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A survey of the Cold Regions Science and Technology Bibliography and other references in the CRREL library was conducted to compile recent information about several Soviet physiogeographic features: permafrost, seasonally frozen ground, snow cover and vegetation. The products of the study are 1) a series of maps presenting the general distribution of these features over the entire Soviet Union and 2) a collection of 57 maps showing the local distribution of ground ice and permafrost.

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PREFACE

This report was prepared by Susan R. Bigl, Research Physical Scientist, of the Geotechnical Research Branch, Experimental Engineering Division, under the general supervision of Dr. Jerry Brown, Chief, Earth Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory.

The author thanks Eleanor Huke, who drafted many of the figures, and Anatoly Fish, who provided useful discussions of Soviet construction regulations and engineering guidelines. Preston Layton and Michael Gnoucheff helped to compile the appendix maps. Mr. Gnoucheff also translated figure captions and legends of those maps taken directly from the Russian literature. Dr. Daniel Lawson and Paul Sellmann provided very helpful technical reviews of the main text and captions.

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US Army Corps of Engineers
Cold Regions Research & Engineering Laboratory

Permafrost, seasonally frozen ground, snow cover and vegetation in the USSR

Susan R. Bigl

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For conversion of SI metric units to U.S./British customary units of measurement consult ASTM Standard E380, Metric Practice Guide, *published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.*

CONTENTS

ILLUSTRATIONS

PERMAFROST, SEASONALLY FROZEN GROUND, SNOW COVER AND VEGETATION IN THE USSR

Susan R. Bigl

INTRODUCTION

This study compiles recent information about several Soviet physiogeographic features: permafrost, seasonally frozen ground, snow cover and vegetation. The major information sources were the Cold Regions Science and Technology Bibliography for the years 1976 to 1982, and references in the CRREL library. Titles older than those cited in the bibliography were found through cross references in more recent works and by personal discussion with other CRREL researchers.

The primary product of this study is a series of maps depicting the general distribution of each feature throughout the USSR. A short text describes the distribution shown on the maps. A second product is a collection of 57 maps showing the local distribution of ground ice and permafrost in the USSR (Appendix A). Translations of the Russian captions in the Appendix have not been greatly edited to avoid changing the original meanings of the authors. However, some liberties have been taken in the body of the report in an attempt to make the translations conform to North American conventions.

PERMAFROST

Figure 1 depicts the distribution of permafrost on exposed land masses in the Soviet Union as published for engineering design purposes by the Research Institute on Foundations and Underground Structures (1969). The region of continuous permafrost is subdivided into zones in which depths of the permafrost are typically within the same 100-m range. Within any one of these zones, the thickness does not necessarily increase northward, but varies locally with the relief and underlying geology.

Two distinct permafrost zones exist south of the continuous permafrost. One of these has large islands of permafrost surrounded by unfrozen ground. The islands typically cover 40-80% of the total surface area in this zone.

The other zone has essentially the same configuration, but the coverage of permafrost is more sporadic. Unfrozen ground underlies most of this region, and small permafrost islands cover only 5-30% of the surface area.

The ground temperatures of permafrost at a depth of 10 m, which is below the layer affected by seasonal temperature variation, are shown in Figure 2. In general, ground temperatures decrease northward and with increasing elevation.

Figure 3 is a map of the permafrost in the Soviet Union, compiled from a series of geocryological maps at the scale 1:2,500,000, and published recently by Kudriatsev et al. (1980) and Gavrilova (1981). The map illustrates three basic features of the permafrost: 1) distribution according to its variability over the area and throughout its depth, 2) heat exchange level as derived from the typical mean annual temperatures for a given latitudinal or altitudinal zone, and 3) thickness. This newer map shows the same basic pattern as Figure 1, with further refinements mainly based on heat exchange. The southern, discontinuous permafrost region is subdivided into several zones related to the percentage of area with permafrost.

Areas where layers of relic Pleistocene permafrost exist at depth are also indicated; they occur in northeast European USSR, western Siberia, and the southern part of central Siberia. The top of the relic layer lies at 80-250 m below the ground surface. Its temperature is slightly below 0°C, and it may range in thickness from 200 to 300 m (Kudriatsev et al. 1980). In areas with relic permafrost where present-day permafrost also extends from the surface, the permafrost is in two layers. In western Siberia the southern boundary of relic permafrost extends 2-3° in latitude farther south than the present-day permafrost. In northeast European USSR and in central Siberia the present-day permafrost boundary lies farther south than that of the relic permafrost, and the two-layer band of permafrost is narrow.

Permafrost below the Arctic Ocean is divided into a deep ocean zone and a shelf zone (Fig. 3). This subsea permafrost formed at a time when the overlying water had receded and the region existed as dry land. The area subsequently became submerged, and ice in the upper layers of the deposits melted and mixed with seawater. This resulted in a layer of sediments saturated with seawater, the temperature of the water being below 0°C today; these deposits are termed kriopegs. Permafrost in the deep ocean zone consists solely of kriopeg materials that are several meters thick and have temperatures from 0.0° to -0.7°C. The shelf zone has kriopeg materials only near the surface. These materials are underlain by a layer of relic permafrost consisting of ice-bonded deposits, which are degrading from above and below. These deposits are present as a wedge within the shelf zone, the thickness of the wedge decreasing away from the coast. For further reference regarding arctic submarine permafrost, consult Vigdorchik (1980), who compiled an extensive bibliography of published information on the subject and discussed its characteristics and sequence of development in detail.

Maps have also been published that depict the types and total amount of ice within the Soviet permafrost. Schematic maps such as those in Figures 4 and 5 show, respectively, the distribution of total ice content and wedge ice content (Vtiurin 1978). In general the higher ice contents in the USSR are within sediments along the northern coast, on the West Siberian plain, and in the northern Lena River valley.

Another topic of discussion in Soviet literature is how man's industrial activities will alter the natural geocryologic conditions. Shvetsov and Bobov (1978) have developed a model for predicting geocryological changes by considering the direct and indirect influences of industrial activities on the natural heat and water exchange. They based their model on documented changes at locations where development had already occurred. Using this analysis, they subdivided the permafrost area into four regions: a northern and a southern zone, each divided into continental and maritime subzones (Fig. 6).

FREEZE-THAW DEPTHS

Typical depths of seasonal freezing in nonpermafrost areas and seasonal thawing in areas with permafrost are shown in Figure 7. Values of the range in thaw depth are positioned at sites where measurements were taken (Nekrasov 1962). These depths vary from 0.5 to 2.5 m, but they show no pattern of distribution, probably due to the scarcity of data and the large diversity of terrain types. Typical depths of seasonal freezing are shown as contours, because there are enough measurements to interpolate between monitoring sites (State Committee on Construction 1973). Depths of seasonal freezing generally increase from the west and southwest to the east and northeast.

VEGETATION

Distribution of vegetation in the Soviet Union is shown in Figure 8. Five vegetation zones are distinguished: tundra, taiga, broadleaf forest, steppe and desert. These are generalized from a detailed vegetation map in the volume Physical Geographic Atlas of the World (Gerasimov 1964).

The tundra zone consists mostly of ground species such as herbs, mosses, lichens and prostrate shrubs. It exists mainly along the northern coast and at the higher mountain elevations (Fig. 8). In the lowland regions, tundra lies within very wet terrain, with much of the area covered by bogs; the mountain tundra is well drained and much drier.

Taiga, which is primarily composed of coniferous forest, covers a majority of the Soviet Union. In Figure 8 the taiga is divided into categories based on predominant tree and terrain types. Forests that include a single tree type (e.g. coniferous, broadleaf or larch) are separated from those with a mixture of these tree types. In this classification system, larch was separated from coniferous and broadleaf species because larch forests and open woodlands cover such a large area of the country and because larch is a conifer with deciduous needles. Larch forests have dense canopies during the summer where terrain conditions permit, but during the winter, larches lose their needles. Regions shown as dark coniferous, with some pine or mixed coniferous, can generally be considered densely covered.

Forests that include mainly temperate broadleaf trees are found in central European USSR (Fig. 8). The primary species are oak, beech and linden with some hornbeam and aspen. Mountain and lowland terrain is not distinguished in this vegetation zone.

Steppe vegetation is present in a band across southwestern USSR and in areas of southern Siberia. It consists primarily of grasslands, similar to the prairies of the U.S., mixed with some shrubs. The wooded steppe additionally contains trees and occurs at higher elevations in the steppe vegetation zone.

Desert vegetation is present in southwest USSR. It is fairly diverse, including shrubs growing on sands, grasslands, and shrubland similar to sagebrush country in the U.S. Because of cartographic scale restrictions, floodplain vegetation, which consists of grasslands and some forests, was not shown separately in Figure 8 when it was surrounded by desert.

SNOW COVER

Rikhter described snow cover in the Soviet Union in two classic Russian monographs: Snow Cover, Its Formation and Properties (1945) and The Role of Snow Cover in Physical Geographic Processes (1948). He covered aspects of the dynamics of the snow cover, its properties and the connection between snow cover and climatic, geomorphological and other natural processes. He also presented a map of snow cover regions based on depth of snow and length of cover (Fig. 9).

Kotliakov (1968) and Lyndolph (1977) also described the snow cover in the Soviet Union, including its mean maximum depth and mean dates for its establishment and disappearance (Fig. 10 and 11).

The seasonal dynamics of snow depth in the Soviet Union are presented in more recent publications by Kopanev (1978) and Kopanev and Lipovskaia (1976) of the Main Geophysical Observatory in Leningrad. They used data from snow surveys made during the period 1936-1965 to develop maps that present the average snow depth during the last ten days of each month from October to April (Fig. 12). For the most part the data were from sites beneath tree cover in forests and in forest glades. In some cases, data from exposed, open areas were also used. Because differences in snow depth result from the great variety of natural conditions at observation sites, these measurements give only a general picture of the snow distribution.

The first snow in the European territory appears during October and November. Usually the establishment of a stable snow cover is preceded by a pre-winter period during which the snow repeatedly covers the ground and then melts. The number of snowfalls and snowmelts increases from north to south, while the length of the pre-winter season decreases towards the east.

By the end of October (Fig. 12a) a stable snow cover is usually formed in the Urals and the adjacent northern regions of the European USSR. Over most of the Asian territory a stable snow cover is formed in the first half of October, with depths ranging from 10 cm to less than 30 cm (Fig. 12a). Exceptions to this are the Baikal, Transbaikal and Amur regions in the extreme southeast.

The greater part of the European territory still does not have a stable snow cover by the last ten days of November (south of dashed line, Fig. 12b), although the northern regions have snow depths greater than 10 cm. By this time, depths in the Urals have increased to greater than 40 cm. In the

Asiatic territory most areas have a little more than 20 cm of snow, while higher elevations on the Kolyma Peninsula and the central Yenisey valley have greater than 30 and 40 cm, respectively.

By the end of December (Fig. 12c) a stable snow cover is formed over the entire Soviet Union, but its depth has increased nonuniformly. The southern and western parts of the European territory are still covered with less than 10 cm of snow, while the northern part of the country has snow 20-40 cm deep and the highest parts of the Urals have over 50 cm. In the Asian territory the greatest snow depth is in the central Yenisey valley, where depths range from 40 to over 50 cm. Most of eastern Siberia has depths that range from 30 to 40 cm, whereas depths in coastal and southern regions are in the 10- to 30-cm range.

In the last ten days of January (Fig. 12d) the area of snow with depths less than 10 cm is decreased considerably, including the southern and western parts of the Ukraine and the southern Volga region. Most of these areas are covered by 10-20 cm. The entire central European territory has snow depths from 20 to 40 cm. Northern sections have greater than 40 cm, and a larger area over the Urals has depths of more than 50 cm. January changes in the Asian territory include even higher snow depths over the central Yenisey (greater than 60 cm), the Kolyma Peninsula (over 50 cm) and the Kamchatka Peninsula (areas with over 60 cm).

Figures 12e and f show that snow accumulation reaches its peak in February and March. In northern and central areas of European USSR, snow ranges from 30 to 50 cm deep, and the Urals accumulate over 60 cm by the end of March. In southern USSR at this time, though, snow is already melting, and areas below 40° latitude become free of snow. In the Asian territory, snow build-up continues. In the central Yenisey valley, snow accumulates to over 80 cm, while areas covered by greater than 50 cm in the Kolyma Peninsula and central Siberia increase in extent.

By the end of April (Fig. 12g) the overall extent of the snow cover is greatly reduced, especially in the European territory. Snow remains north of 58°N latitude, but depths are only 10-20 cm. In western Siberia, snow also exists only north of 58°N, but significant amounts are present along the seacoast (greater than 40 cm) and in central Yenisey valley (greater than 50 cm). At the end of April a stable snow cover exists over all of eastern Siberia. Large areas on the Kolyma and Kamchatka peninsulas and in the Lena valley still have greater than 50 cm of snow.

The final disappearance of the snow cover in the European territory comes at the end of April or the beginning of May. In the Asian territory this period lasts from April (in the south) to June (in the north). The total duration of snow cover, in general, increases with latitude from 20 to 260 days (Fig. 13).

Maximum snow depth is depicted in Figures 14-16 according to the snow survey data for 1935-1965. Figure 14 shows the mean maximum values, while the two subsequent maps have the extreme (maximum and minimum) values.

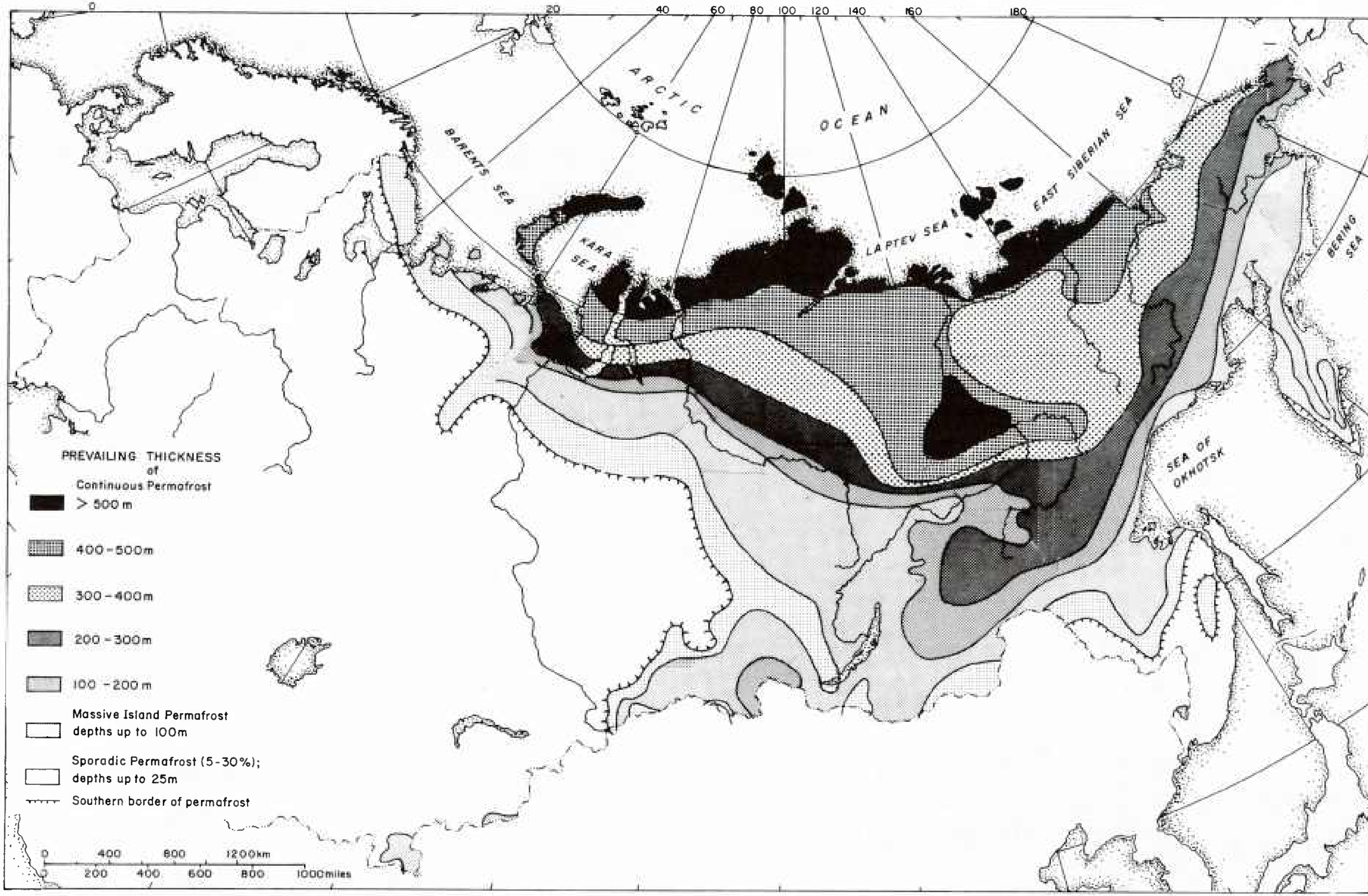


Figure 1. Permafrost depth in the USSR. (After Research Institute on Foundations and Underground Structures 1969.)

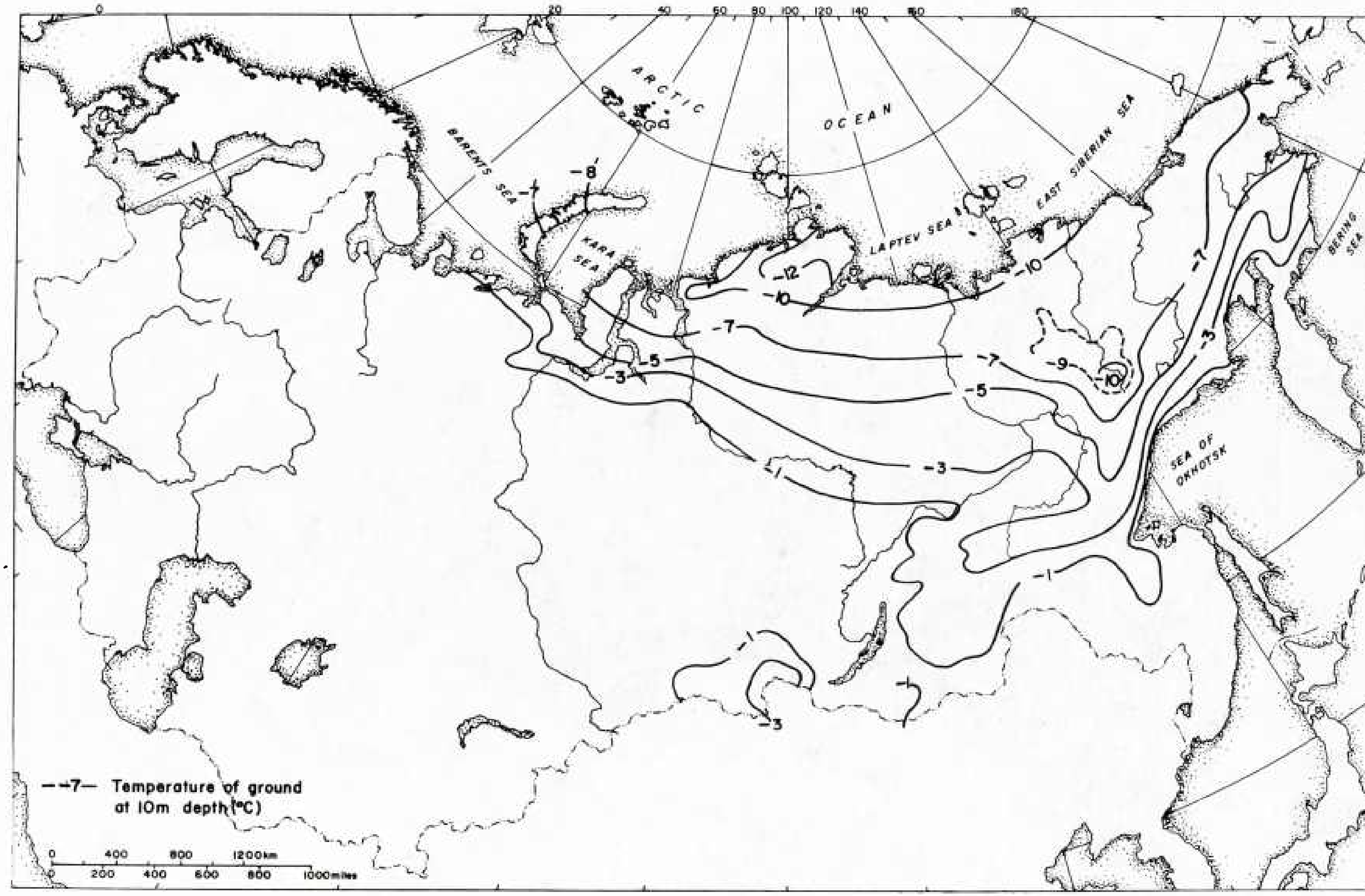


Figure 2. Permafrost temperature at a depth of 10 m in the USSR. (After Research Institute on Foundations and Underground Structures 1969.)

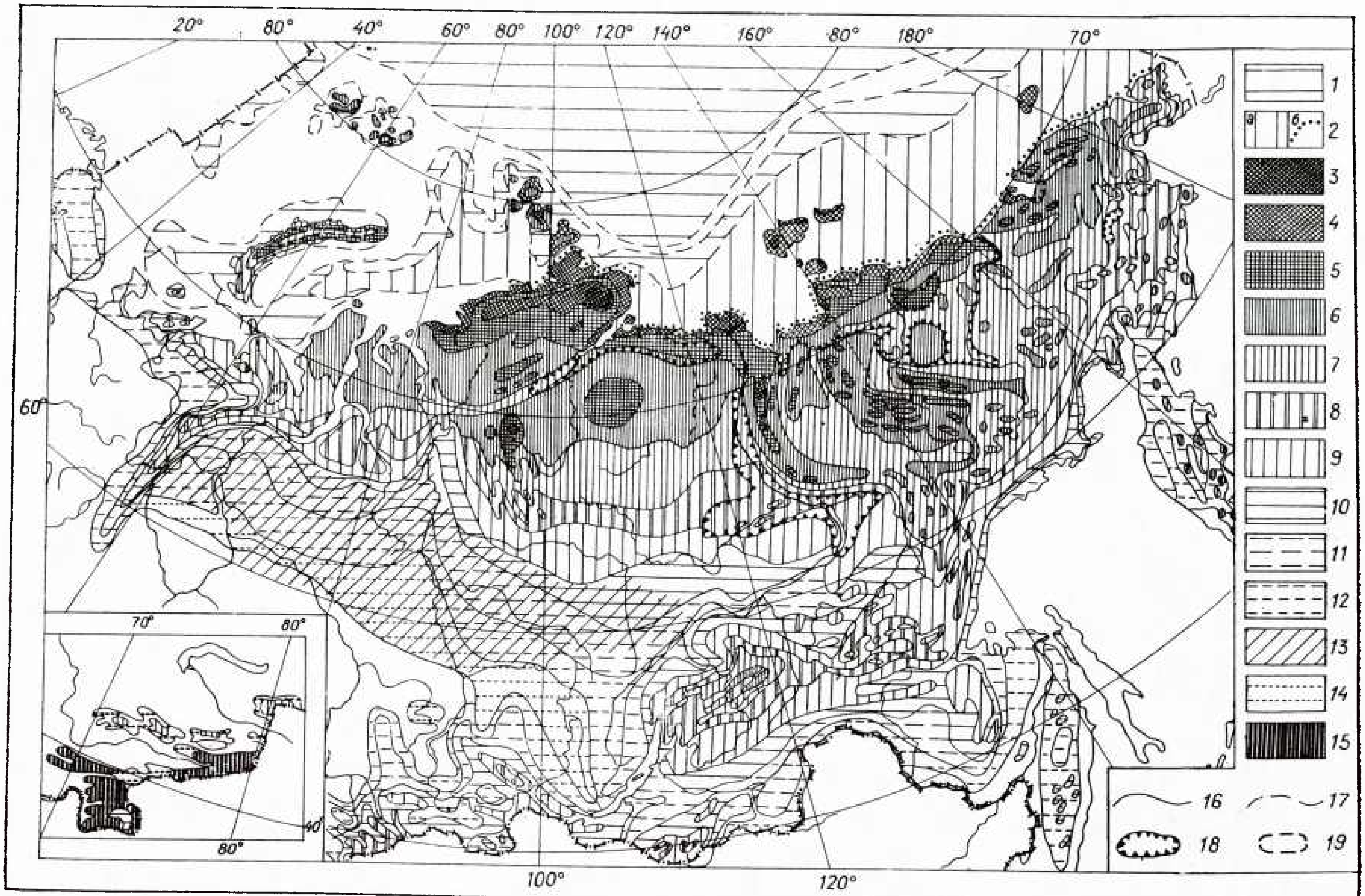


Figure 3. Permafrost regions of the USSR, with inset of Tien Shan/Pamir region. (After Gavrilova 1981.)

Legend - Figure 3

Ocean Permafrost Region

1 - Ocean permafrost zone including saline water at below 0°C - kriopegs (according to Ya.V. Neizvestnov).

2 - Shelf permafrost zone including kriopegs and:

a) large islands of present-day permafrost

b) large islands of relic permafrost (according to Ya.V. Neizvestnov)

Northern Permafrost Region

Continuous permafrost zones, including mean annual temperature (t_m) and thickness (T)

3 - t_m below -13°C, T > 800 m

4 - t_m -11° to -13°C, T = 500-700 m

5 - t_m -9° to -11°C, T = 400-600m; in mountain ranges up to 1000 m or more

6 - t_m -7° to -9°C, T = 300-500 m; in mountain ranges up to 500-900 m

7 - t_m -5° to -7°C, T = 200-400 m; in mountain ranges up to 300-500 m

8 - t_m -3° to -5°C, T = 200-400 m

9 - t_m -1° to -3°C, T = 100-300 m

Southern Permafrost Region

Discontinuous permafrost zones, including mean annual temperature (t_m) and thickness (T)

10 - Large permafrost islands (70-80% of the area occupied by permafrost); t_m 0° to -2°C, T to 100 m; in Western Siberia to 200-300 m; t_m of thawed materials +1° to 0°C

11 - Smaller permafrost islands (40-60%); t_m 0° to-1°C, T = 50-70 m; in Western Siberia 100-200 m; t_m of thawed materials +2° to 0°C

12 - Sporadic permafrost (5-10%); t_m = 0° to -0.5°C, T = 15-20 m; in Western Siberia to 50 m; t_m of thawed materials +4° to 0°C

Other

13 - Relic permafrost (according to V.V. Baulin, N.G. Oberman)

14 - Zone of deep seasonal freezing of materials with short-term and scarce islands of permafrost (up to 5%); t_m = 0°-0.5°C, T up to 10-20 m

15 - Zone of sharp change with altitude; t_m from 0° to -13°C and below; T up to 1000 m and more

16 - Boundary between geocryological zones

17 - Boundary between zones with kriopegs

18 - Boundary of syngenetically frozen deposits with wedge ice

19 - Boundary of subglacial permafrost zone; t_m from 0° to -12°C; T = 0-500 m

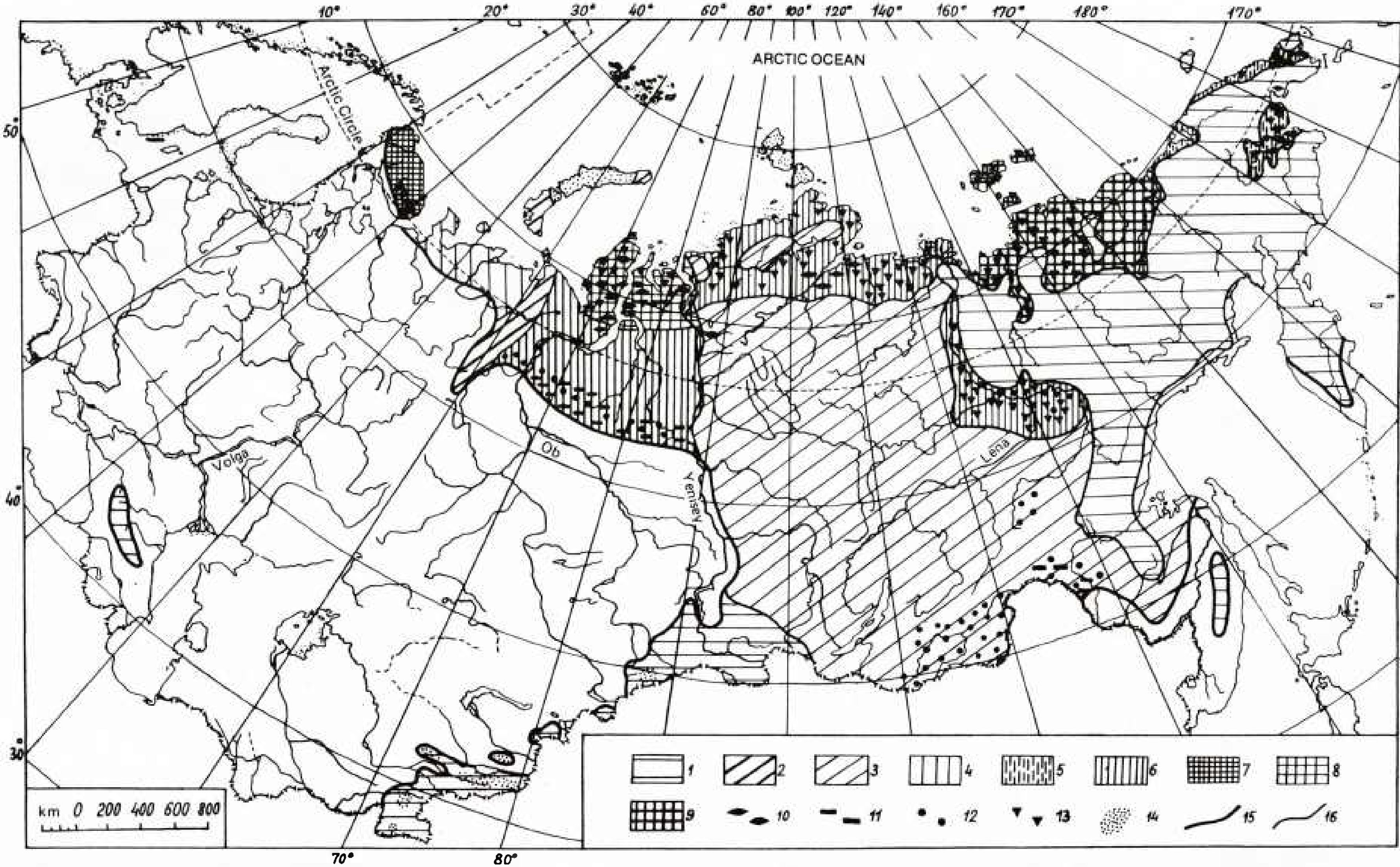


Figure 4. Total visible ice content of permafrost (including all ice types). 1--3% to a depth of 50 m; 2--10-20% to a depth of 5 m; 3--10-20% to a depth of 10 m; 4--20-30% to a depth of 10 m; 5--20-30% to a depth of 20 m; 6--30-40% to a depth of 10 m; 7--40-50% to a depth of 10 m; 8--40-50% to a depth of 20 m; 9--40-50% to a depth of 30 m; 10--regions of thick (>3 m), deep (>3 m) massive ground ice in the form of sills; 11--regions of relatively thin (<3 m), shallow (<3 m) sills of primary interstitial ice; 12--regions where frost mounds containing ice cores occur; 13--regions where large volumes of wedge ice occur; 14--contemporary glaciers; 15--limit of permafrost; 16--limits of areas with variable ice content. (After Vtiurin 1978.)

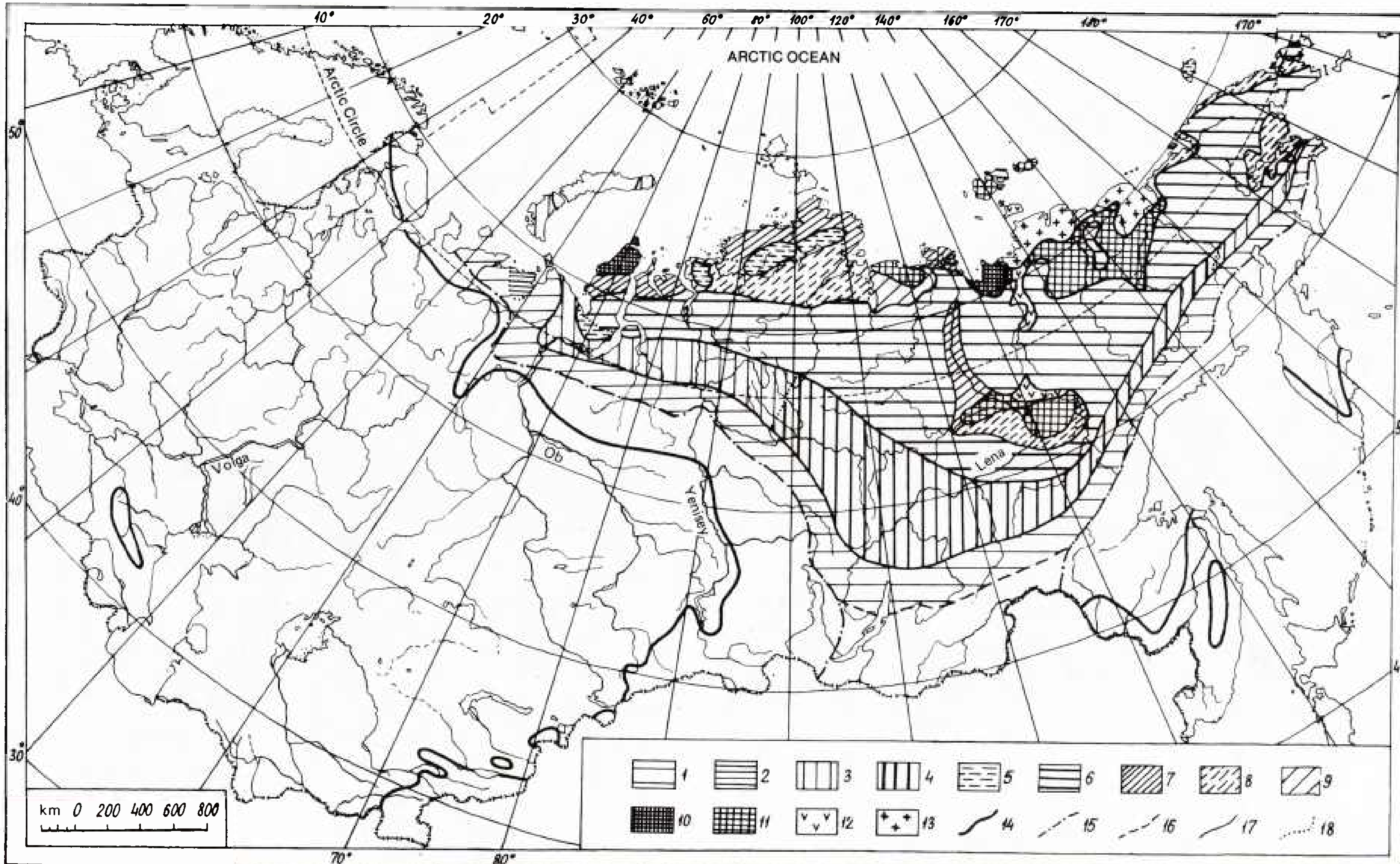


Figure 5. Approximate ground ice volume of permafrost contributed by ice wedges. 1--up to 3% to a depth of 1.5 m; 2--3% to a depth of 2.5 m; 3--3.5% to a depth of 1.5-2 m; 4--3.5% to a depth of 2.5-5 m; 5--5-10% to a depth of 10-15 m; 6--5-10% to a depth of 3-5 m; 7--10-15% to a depth of 5 m; 8--10-15% to a depth of 5-10 m; 9--10-15% to a depth of 10-15 m; 10--15-20% to a depth of 10 m; 11--15-20% to a depth of 10-20 m; 12--20-30% to a depth of 10-20 m; 13--20-30% to a depth of 20-30 m or more; 14--limit of permafrost; 15--southern limit of wedge ice; 16--the same, as found in the trans-Baikal; 17--boundary line of regions with differing ice volumes; 18--boundary line of areas containing ice wedges that penetrate to different depths within one region. (After Vtiurin 1978.)

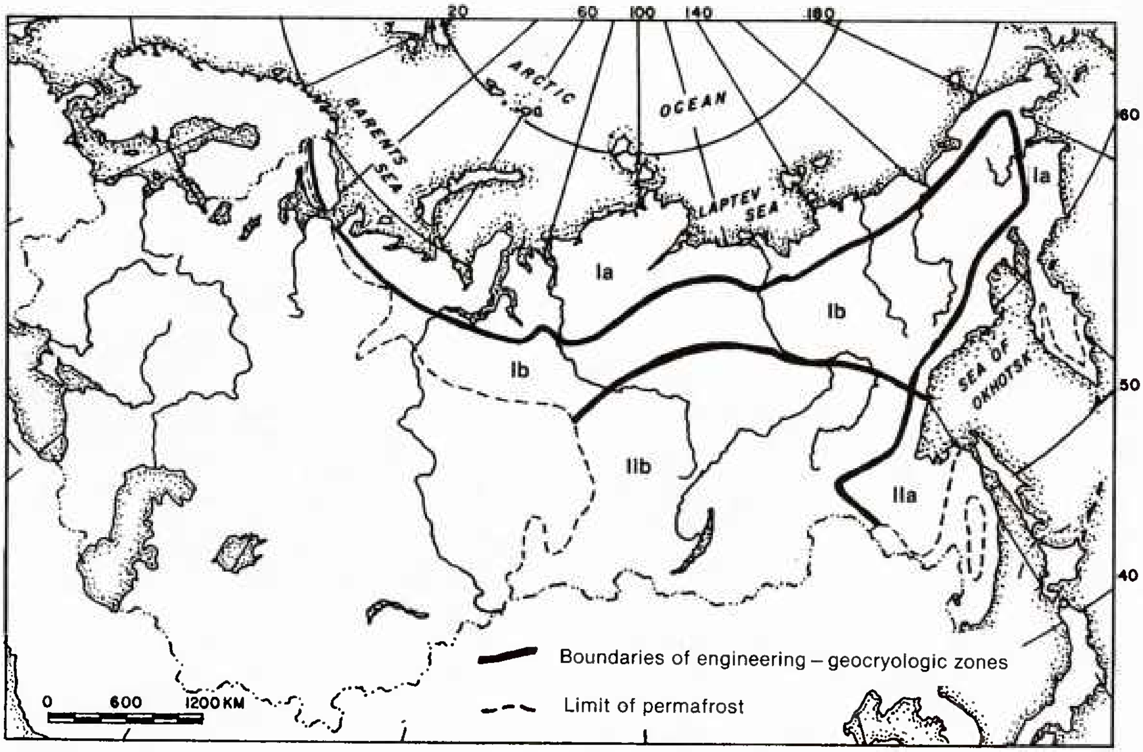


Figure 6. Engineering-geocryologic division for development of permafrost within the USSR. (After Shvetsov and Bobov 1978.)

Engineering-geocryological zones (Roman numbers) and subzones (letter indexes):

I. Northern zone: maximum thicknesses and minimum temperatures of permafrost are inherent to the watersheds; the taliks are coordinated to the relief depressions; the variations of development in a locality can reach maximal values in accordance with the original parameters. Ia - maritime subzone: development leads more often to the reduction of the extent of the frozen layer, to a rise in its temperature, and to an increase in the depth of seasonal thawing. Ib - continental subzone: development involves an increase in the distribution of the permafrost, a decrease in temperature, and a reduction in the seasonal thawing layer.

II. Southern zone: relative maximum thicknesses and minimum temperatures of permafrost are located in areas with less relief; taliks predominate in the watersheds with absolute elevations below 1200 m; the engineering-geocryologic phenomena have less variation in properties than in the northern zones. IIa - maritime subzone: development of a locality essentially causes thawing of the permafrost, an increase in temperature, and an increase in the extent of seasonal thawing; IIb - continental subzone: development leads more often to the new formation of permafrost, a decrease in temperature, and a decrease in the seasonal thawing.

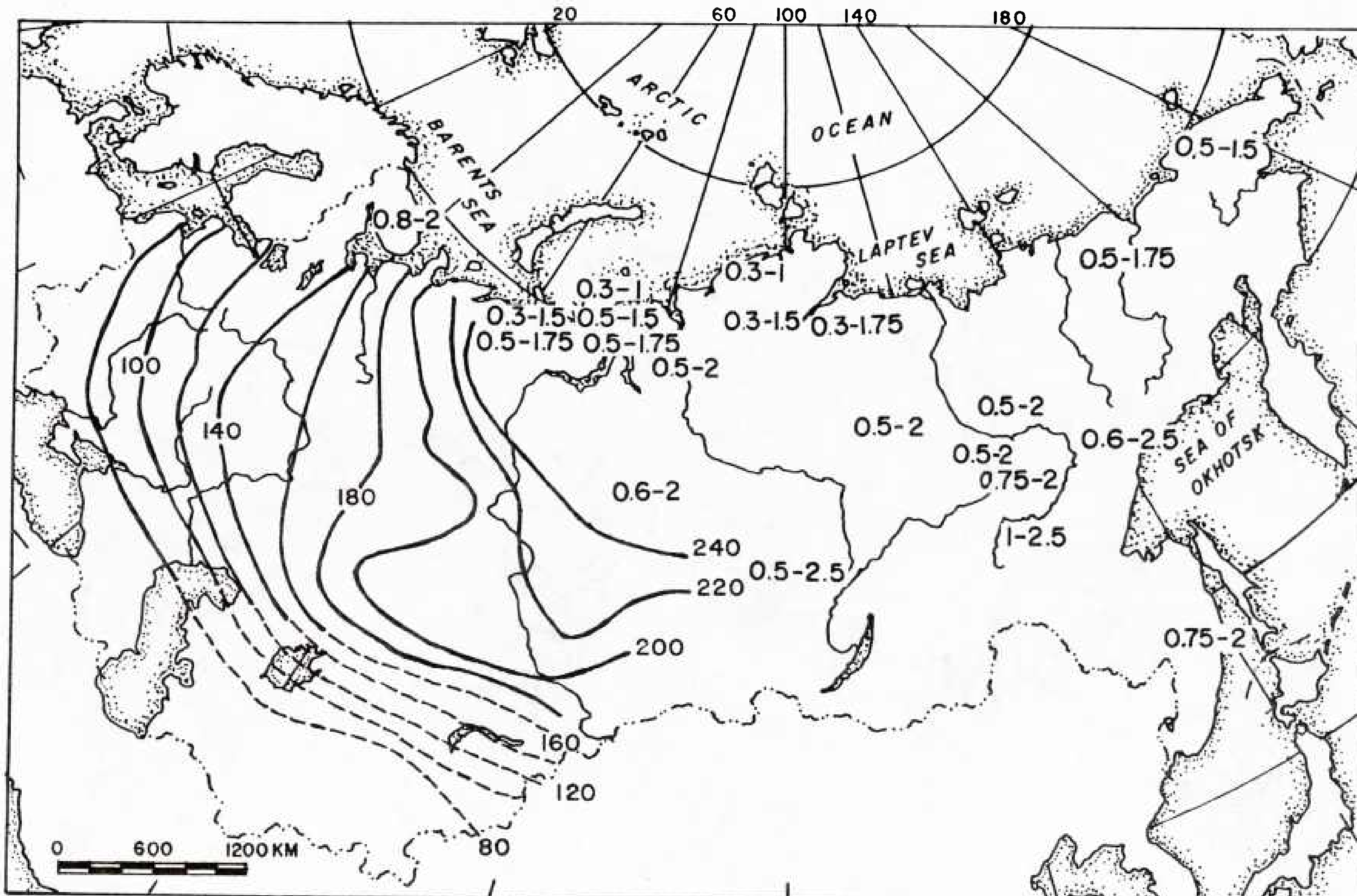
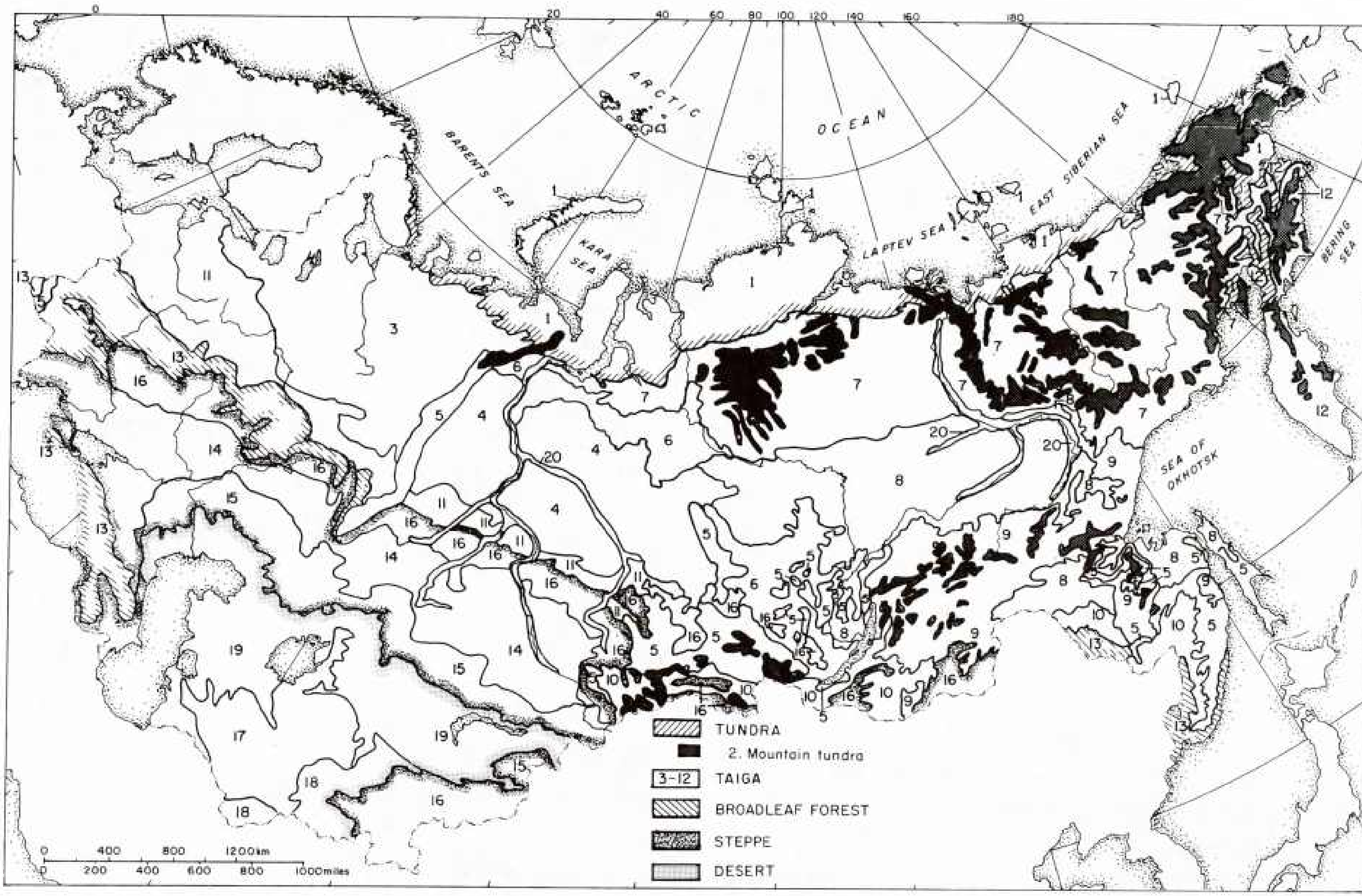


Figure 7. Typical depths of seasonal freezing in centimeters for western USSR, and site observations of seasonal thawing in meters for eastern USSR. (After State Committee on Construction 1973 and Nekrasov 1962.)


ARCTIC OCEAN
BARENTS SEA
KARA SEA
LAPTEV SEA
EAST SIBERIAN SEA
BERING SEA
SEA OF OKHOTSK
TUNDRA
2. Mountain tundra
3-12 TAIGA
BROADLEAF FOREST
STEPPE
DESERT
0 400 800 1200km
0 200 400 600 800 1000miles

LEGEND: USSR Vegetation Map

Tundra (herbs, mosses, lichens, shrubs)
1. Lowland tundra – wet terrain
2. Mountain tundra – drier terrain

3-12

Taiga (coniferous boreal forest)
3. Dark coniferous (spruce) and pine forests; lowland
4. Mixed coniferous (spruce, pine, fir) and pine forests; lowland
5. Dark coniferous and mixed coniferous; mountain
6. Mixed larch – coniferous forest; lowland
7. Larch open woodland; lowland and mountain
8. Larch forest; lowland
9. Larch forest; mountain
10. Mixed larch – coniferous forest; mountain
11. Mixed broadleaf – coniferous subtaiga forest
12. Pacific dwarf formation (pine, alder, birch)

Broadleaf forest
13. Broadleaf forest (pine, alder, birch); primarily mountain

Steppe (treeless grassland)
14. Grasses
15. Mixed shrubs – grasses
16. Meadow and wooded steppe

Desert
17. Shrubs on sand; including bare sands
18. Grasses
19. Shrubs and floodland vegetation

20

Floodplain
20. Meadow and forest vegetation of major rivers

Figure 8. Vegetation in the USSR. (After Gerasimov 1964.)

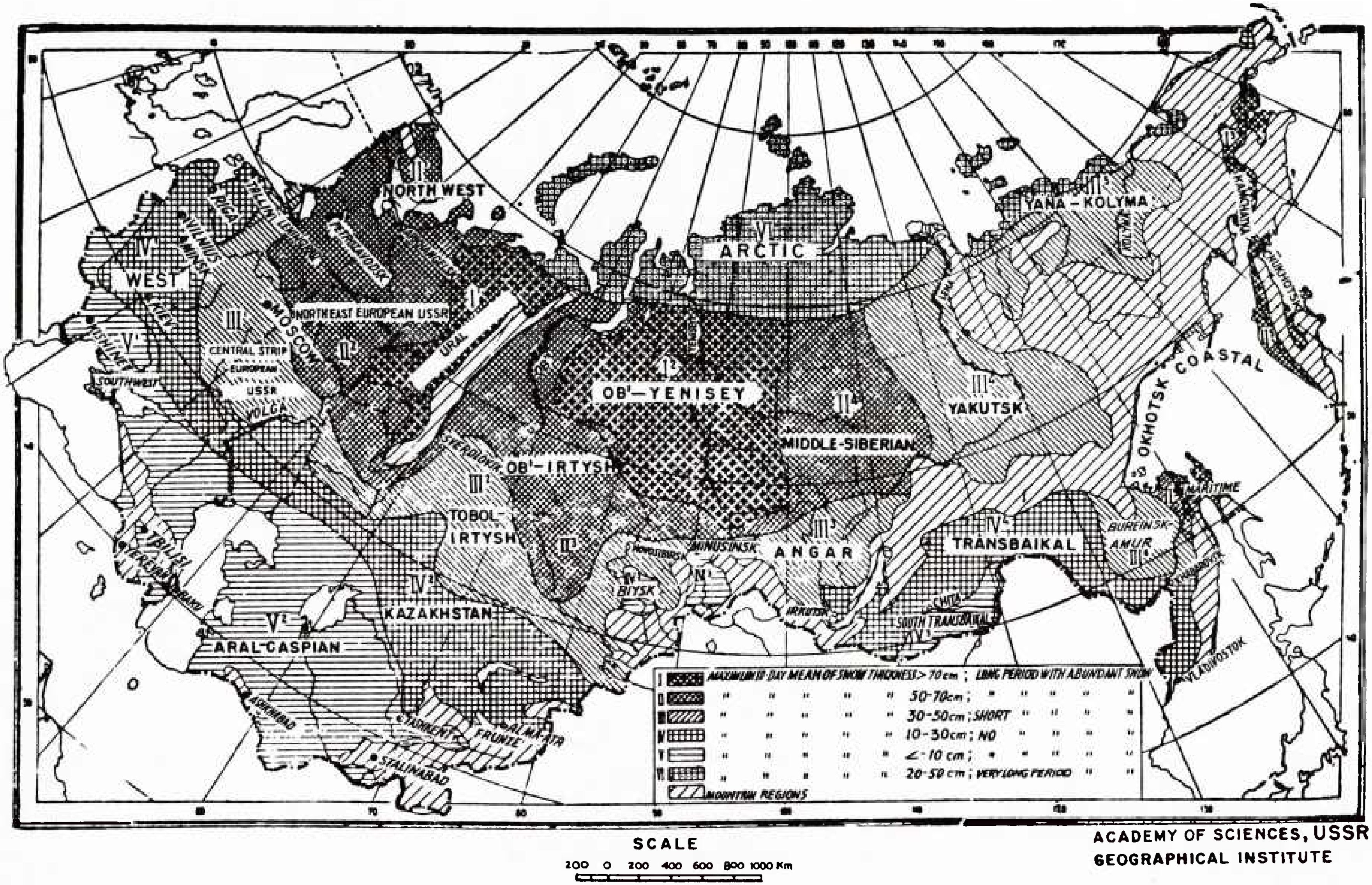


Figure 9. Snow cover regions in the USSR. (After Rikhter 1945.)

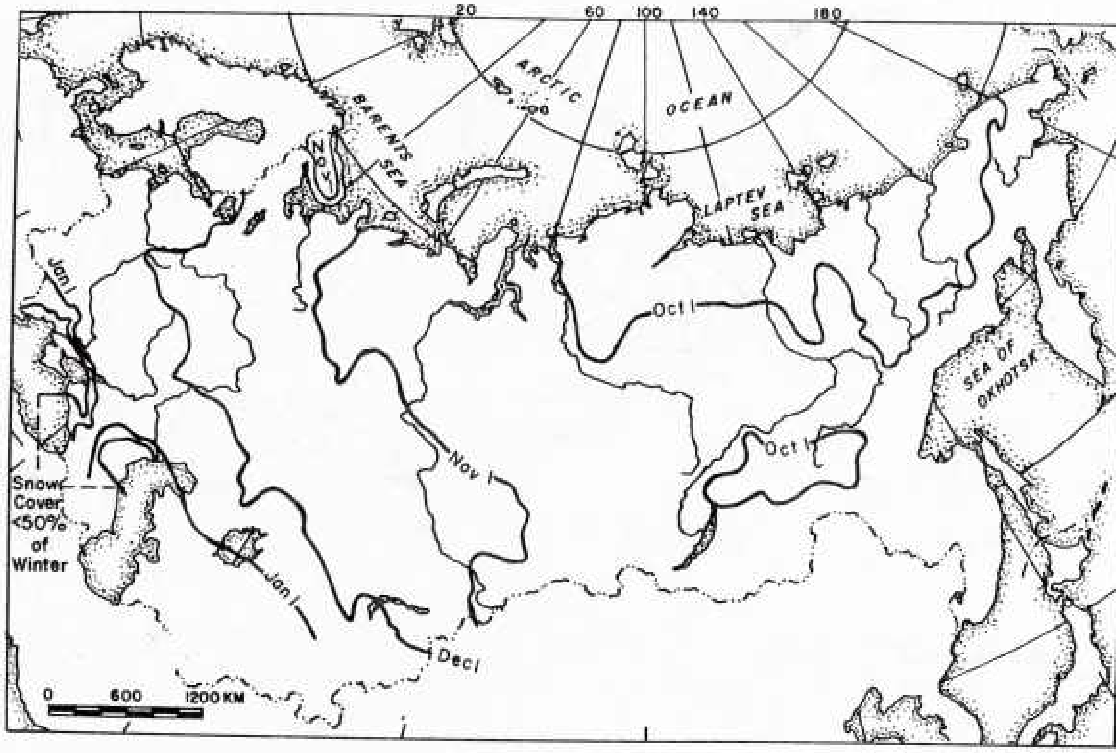


Figure 10. Mean date for establishment of a stable snow cover. (After Lyndolph 1977.)

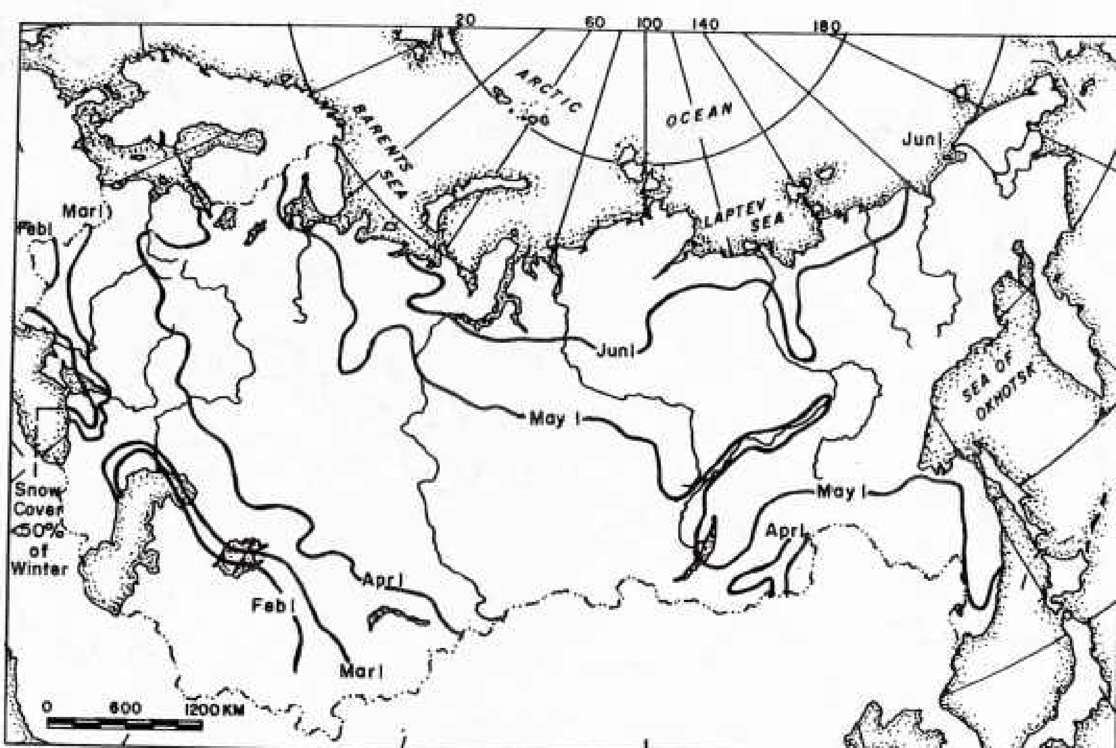
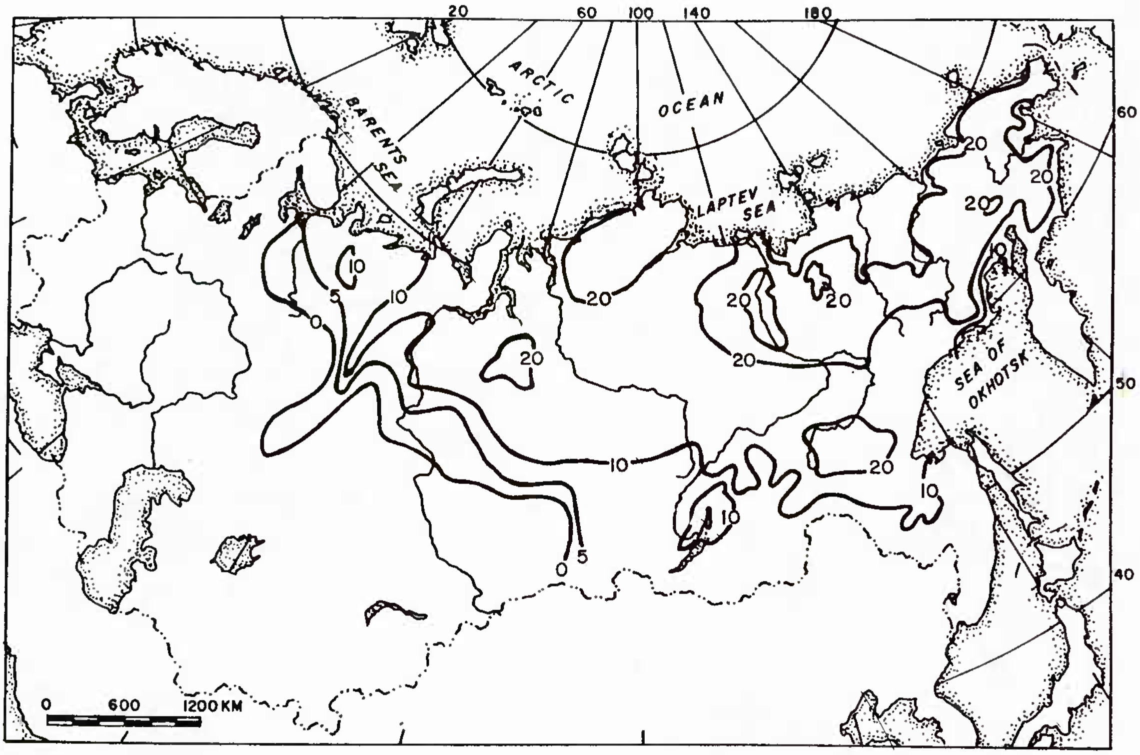
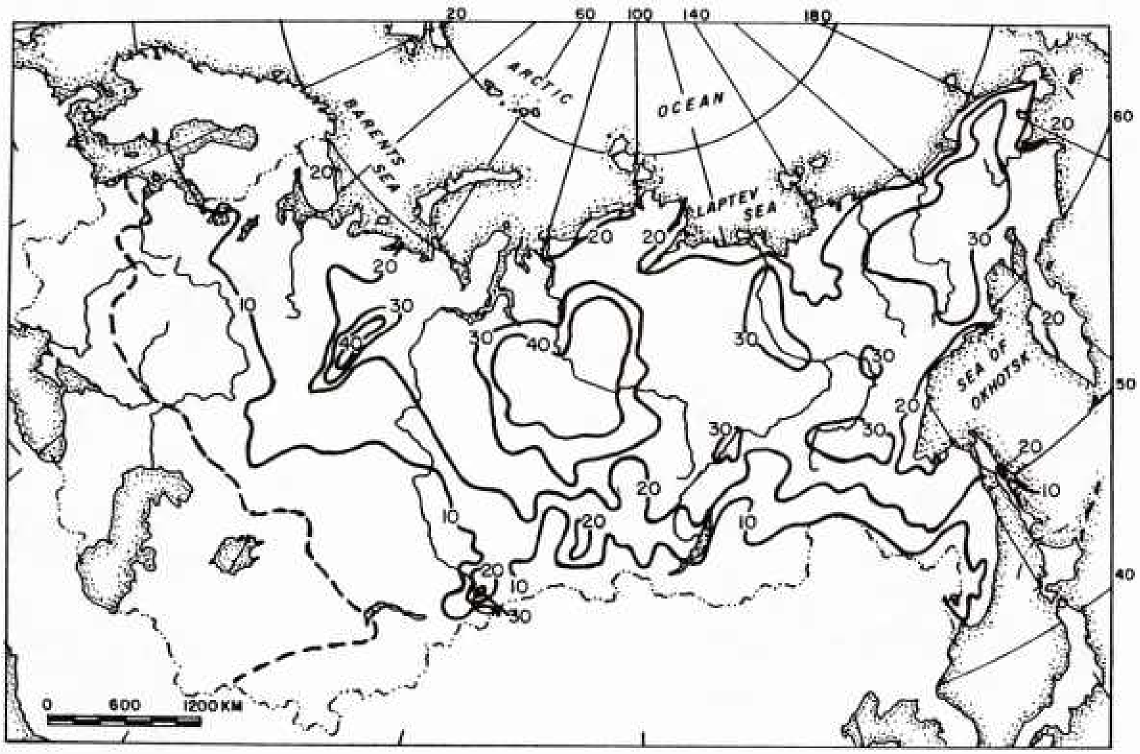


Figure 11. Mean date for disappearance of the snow cover. (After Lyndolph 1977.)

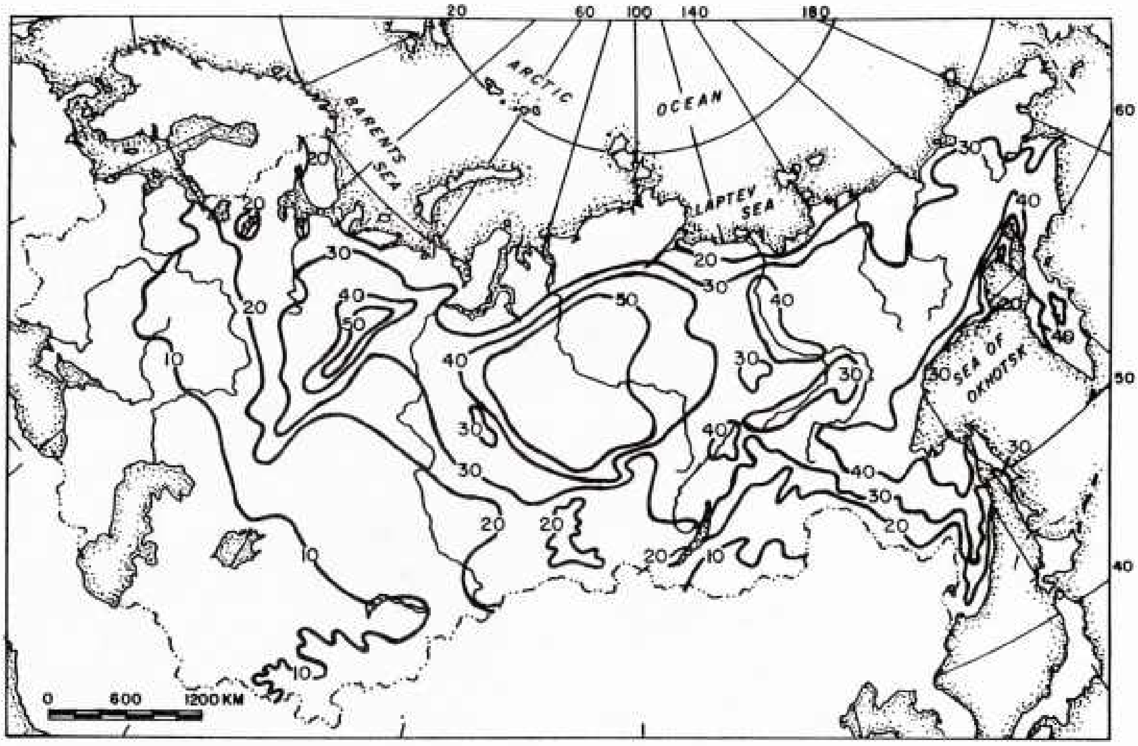


a. October

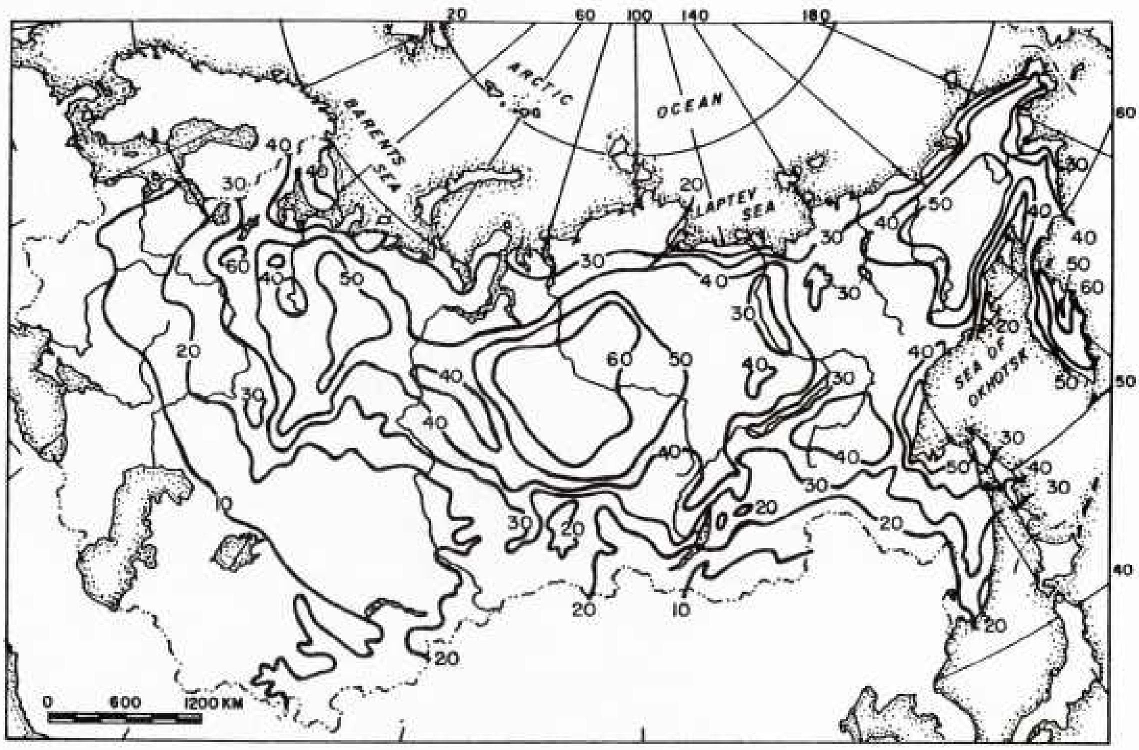


b. November

Figure 12. Thirty-year mean snow depth during the last 10 days of the month (cm). (After Kopanev 1978.)

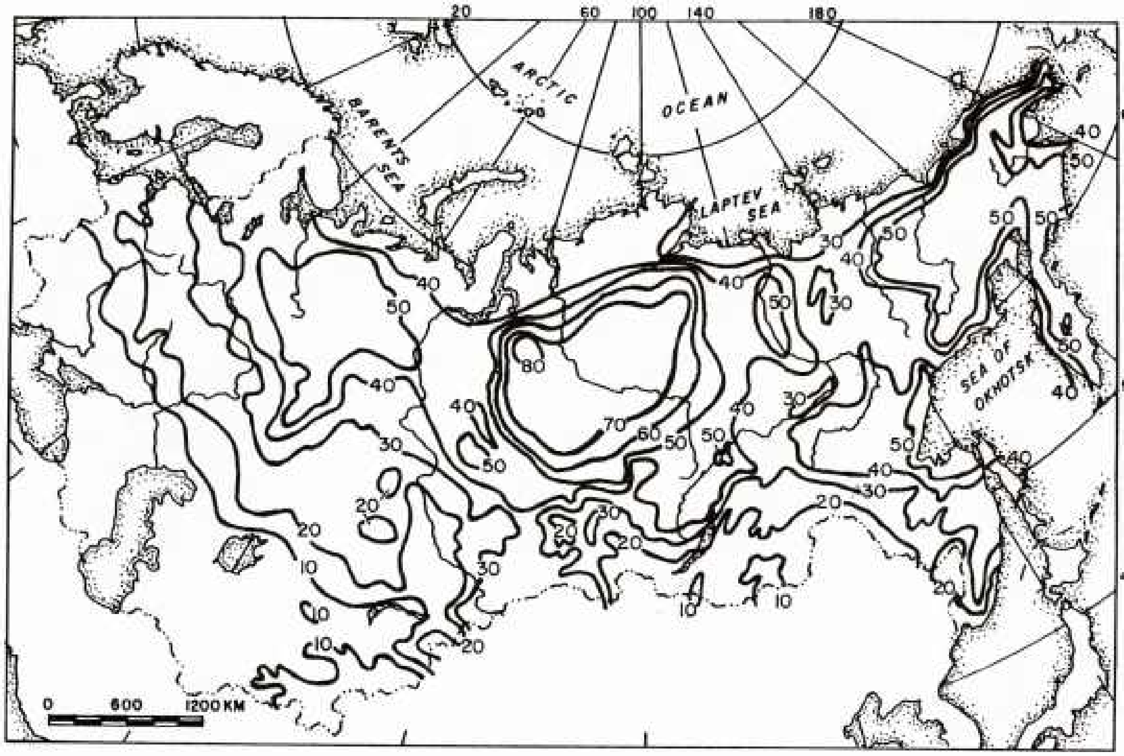


c. December

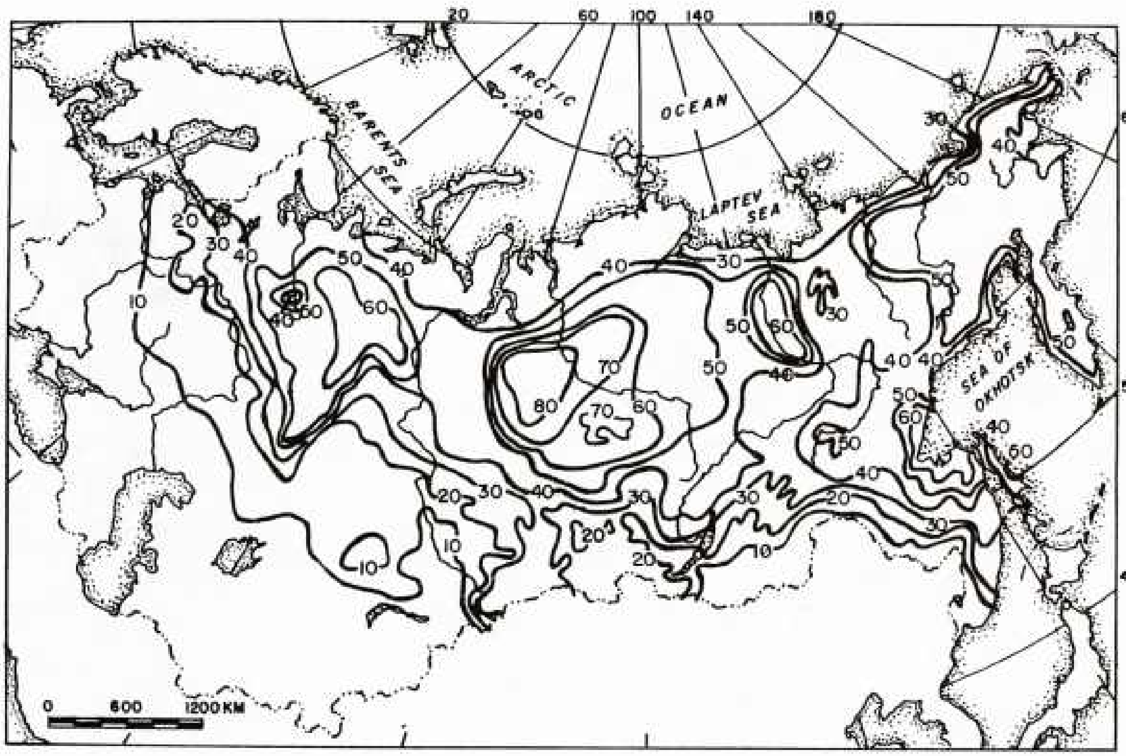


d. January

Figure 12 (cont'd).

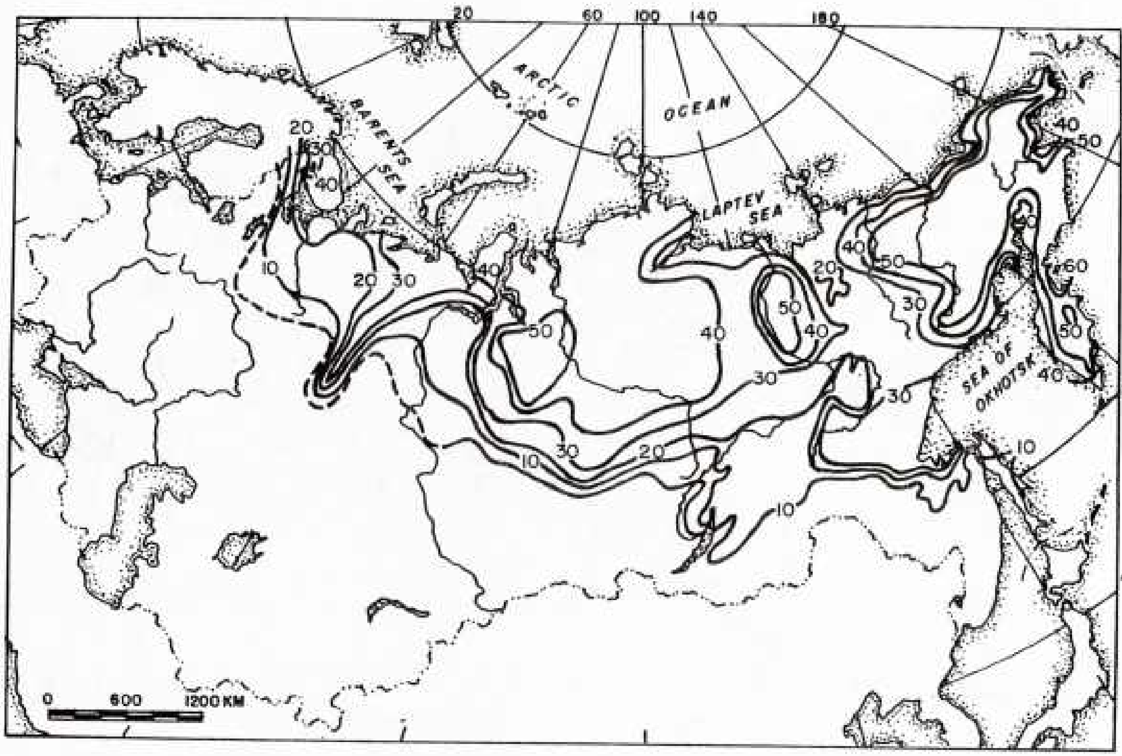


e. February



f. March

Figure 12 (cont'd). Thirty-year mean snow depth during the last 10 days of the month (cm). (After Kopanev 1978.)



g. April

Figure 12 (cont'd).

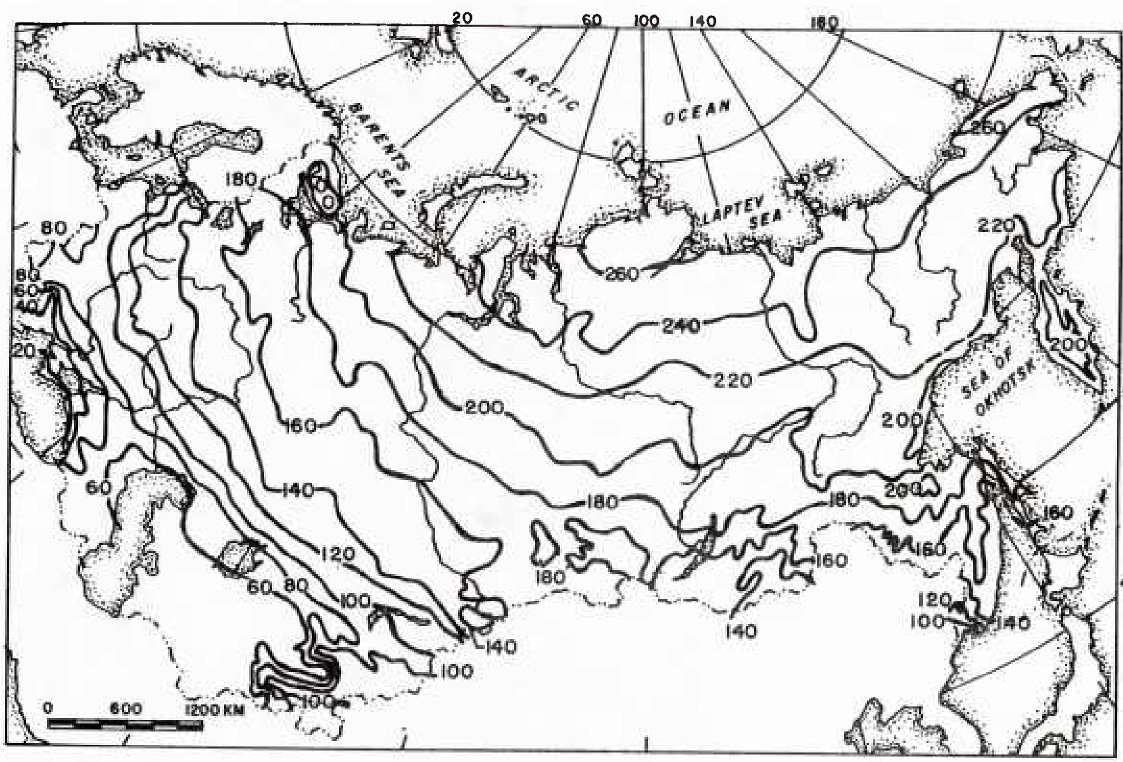


Figure 13. Snow cover duration (days), a 30-year average. (After Kopanev 1978.)

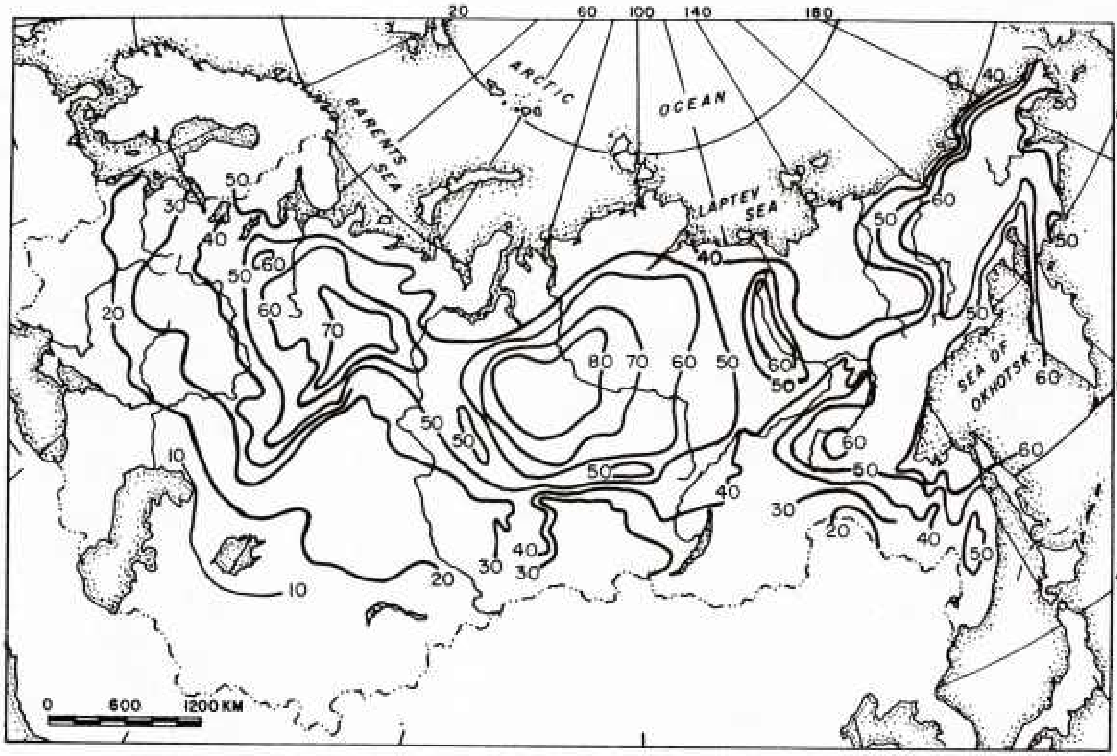


Figure 14. Maximum average snow depth for a 30-year period (cm). (After Kopanev 1978.)

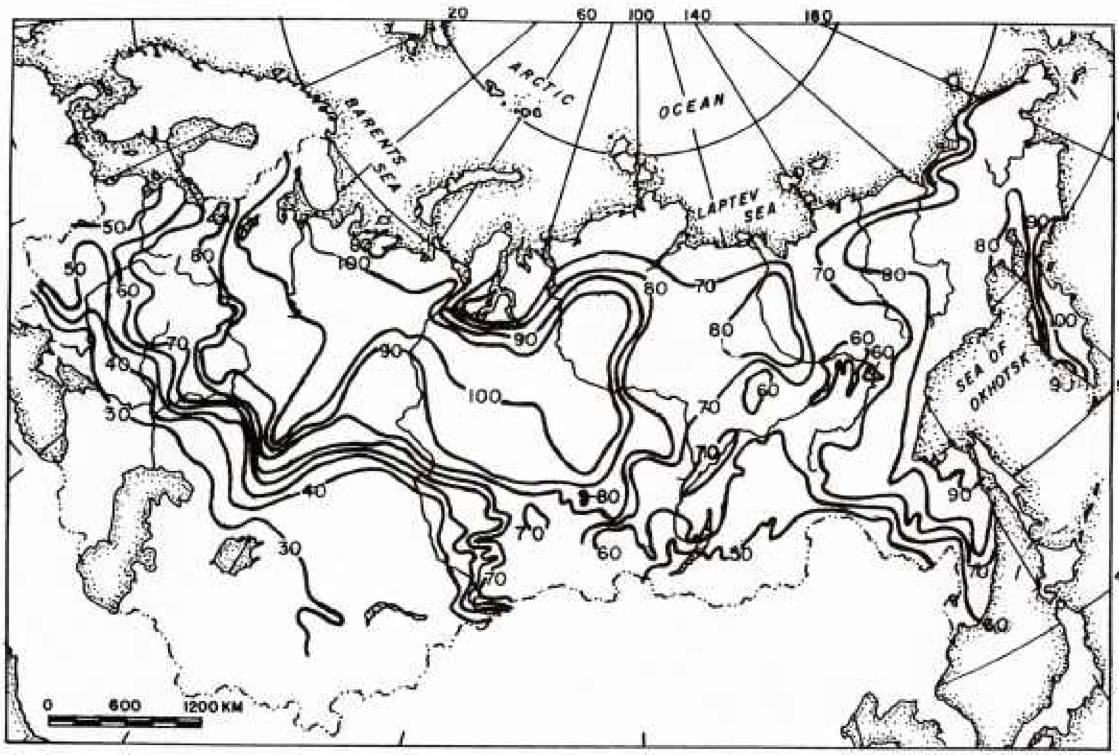


Figure 15. Maximum snow depth for a 30-year period. (After Kopanev 1978.)

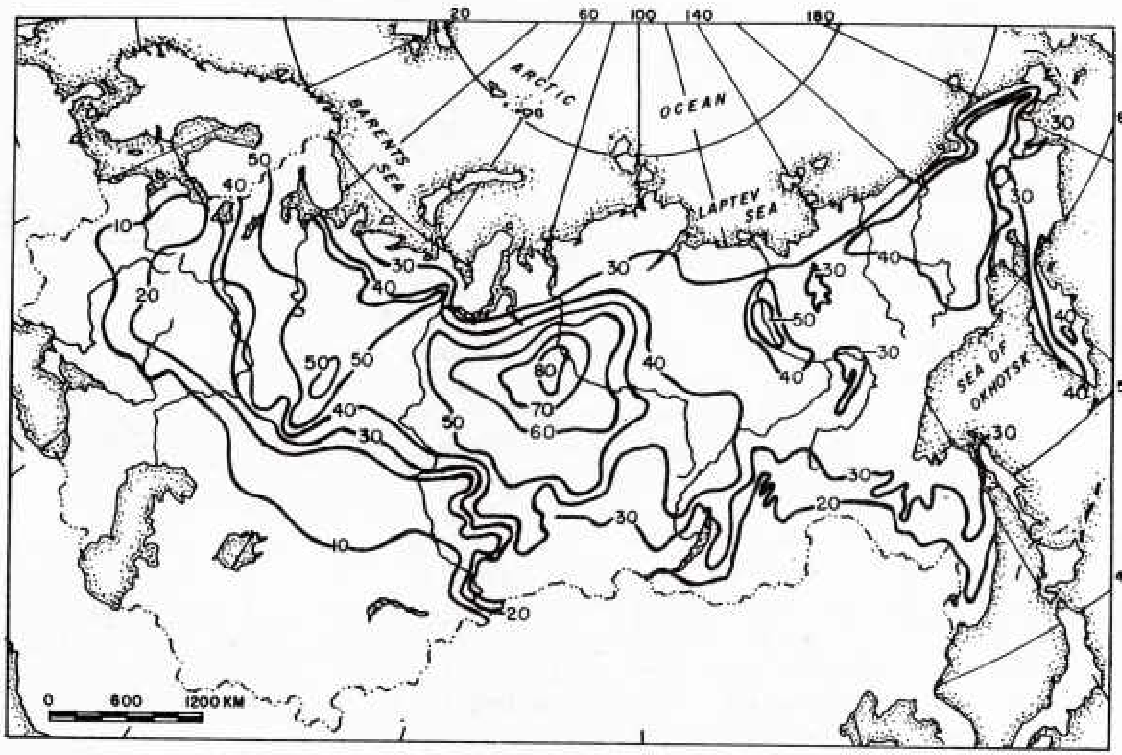


Figure 16. Minimum snow depth from the range of maximum values for a 30-year period (cm). (After Kopanev 1978.)

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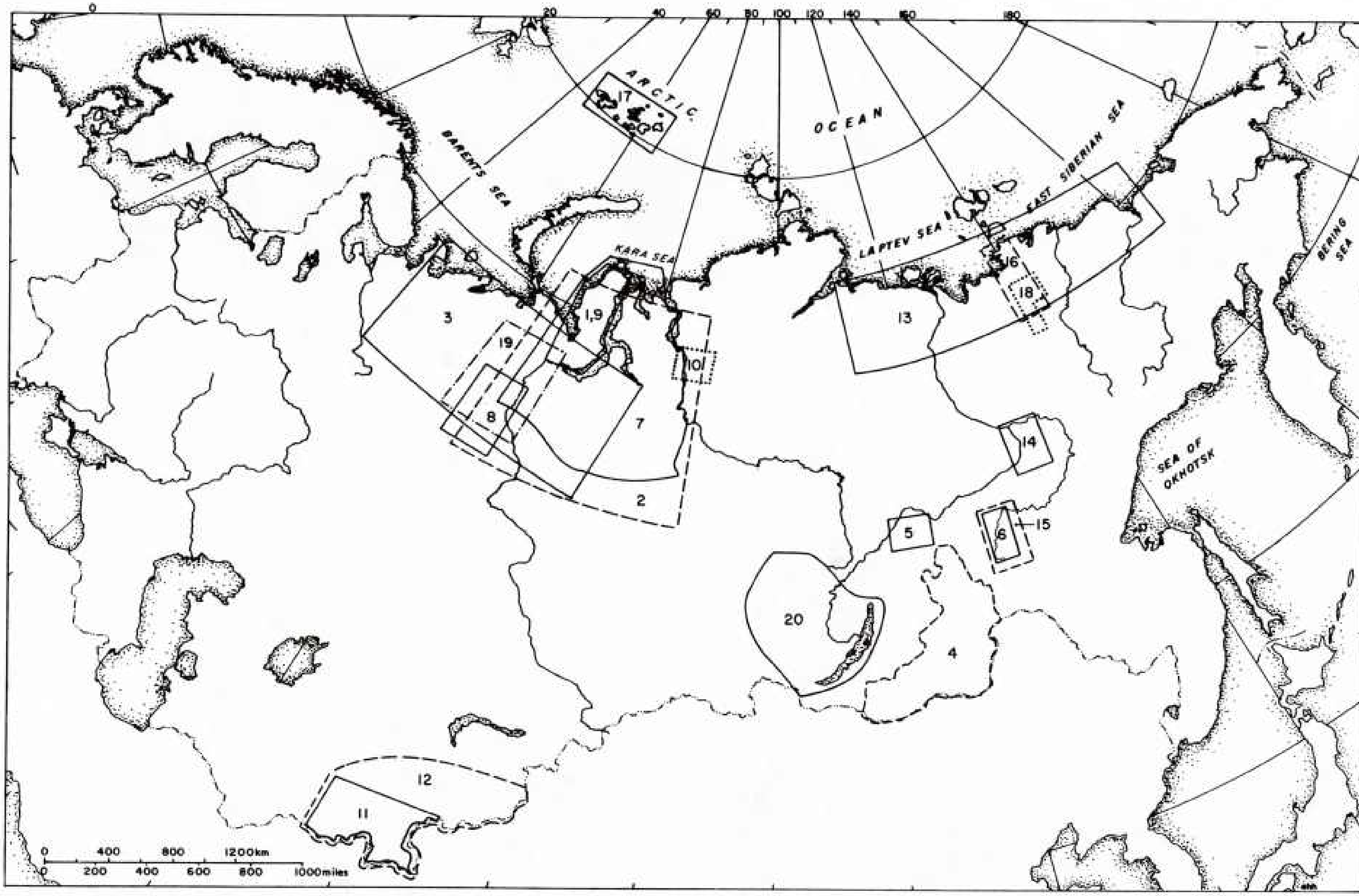
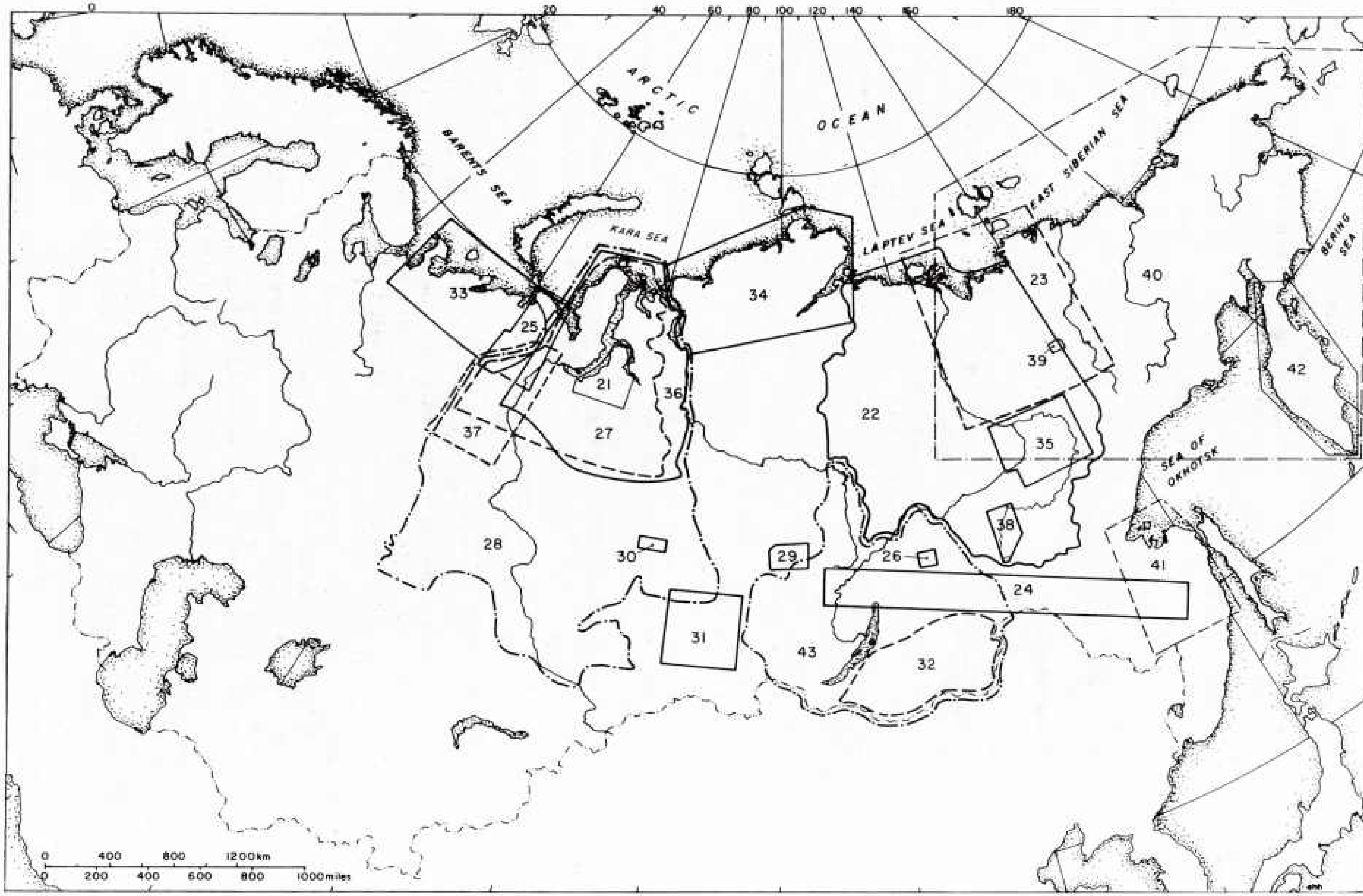
APPENDIX A. LOCAL MAPS OF SOVIET PERMAFROST DISTRIBUTION

This appendix is a compilation of 57 maps of local permafrost distribution in the Soviet Union taken from 43 references. Two index maps show the areas covered by the individual maps. An identification number keys the reference and index map location to the Appendix figure number. Most of this information is current, although some older sources were published in the early 1960s.



Index map 1. Location of Appendix Figures A1-A20.



Index map 2. Location of Appendix Figures A21-A43.

I.D. No[3]

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[3]Identification number on location index map.

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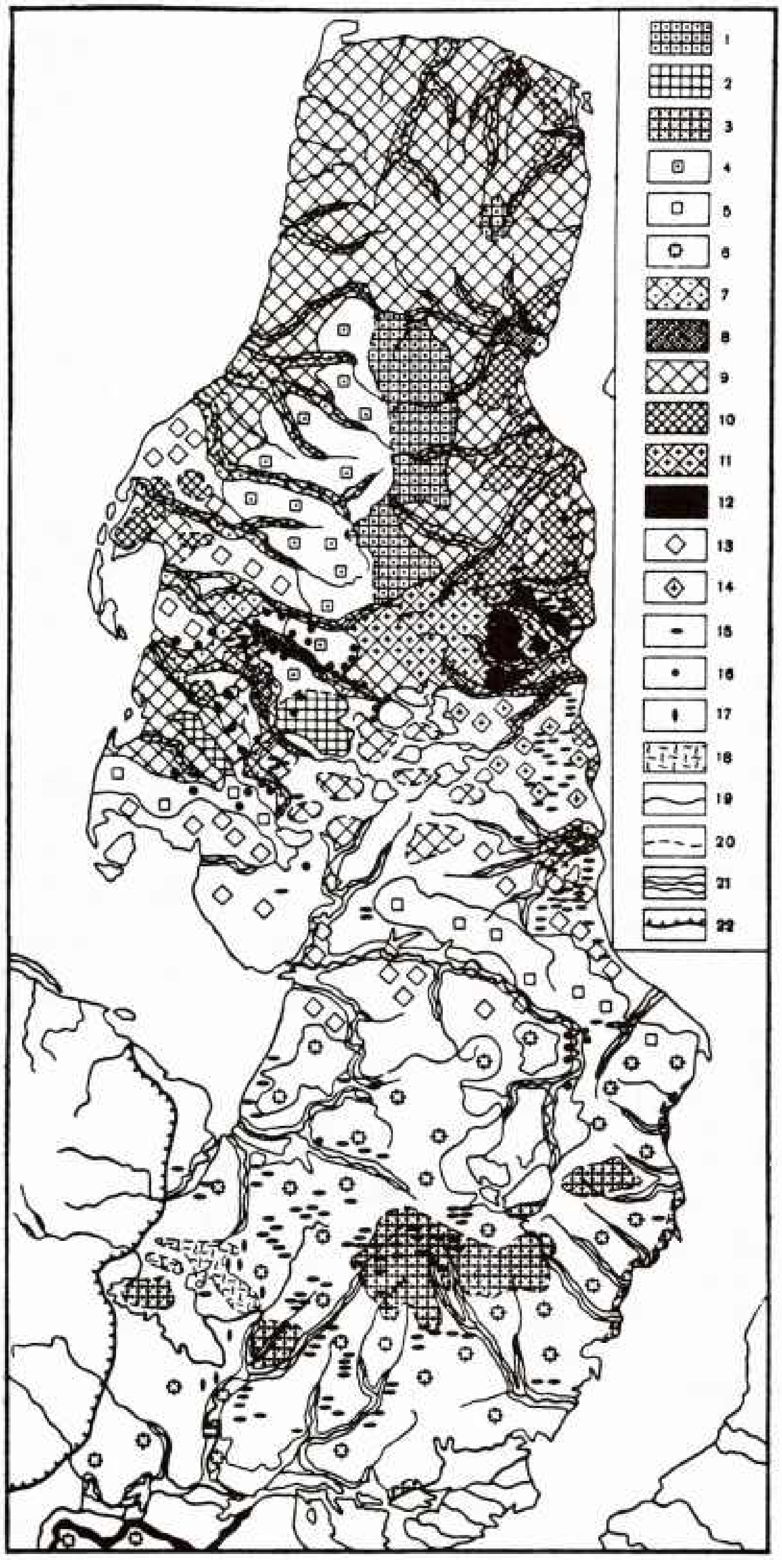

Figure A1a. Distribution of polygonal wedge ice and injected ice on the Yamal Peninsula. (From Badu and Trofimov 1974.)

Legend - Figure A1a

1 - epigenetic polygonal wedge ice in growth stage in mineral soils (macro-ice content bulk Iv = 5-10%);

2 - epigenetic polygonal wedge ice in conservation and melting stages in mineral soils (Iv = 5-10%);

3 - epigenetic polygonal wedge ice in growth and conservation stages in organic soils (Iv <5%);

4,5,6 - separate plots of distribution of above-named ice forms not representable on the scale of this map;

7 - syngenetic polygonal wedge ice in growth stage in alluvial Holocene deposits (Iv - 5-20%);

8 - same (Iv >20%);

9 - relic syngenetic polygonal wedge ice in conservation stage in sea and lagoon deposits of the upper Pleistocene (Iv = 5-20%);

10 - same (Iv >20%);

11 - relic syngenetic polygonal wedge ice, developing epigenetically (2 - stage wedge ice), in sea and lagoon deposits of the upper Pleistocene (Iv 5-20%);

12 - same (Iv >20%);

13,14 - separate plots of distribution of above deposits not representable on the scale of this map;

15 - injected ice - frost mound cores and pingos;

16 - injected ice - sheet formations in the middle and upper Pleistocene sea deposits;

17 - injected ice in upper Pleistocene-Holocene and Holocene lake deposits;

18 - fissured vein ice in Paleozoic rock types;

19 - boundary of the greatest distributions of epigenetic or syngenetic wedge ice;

20 - boundaries of sections with different macro-ice content;

21 - river flood plains;

22 - boundary of exposed Paleozoic rock of the Urals.

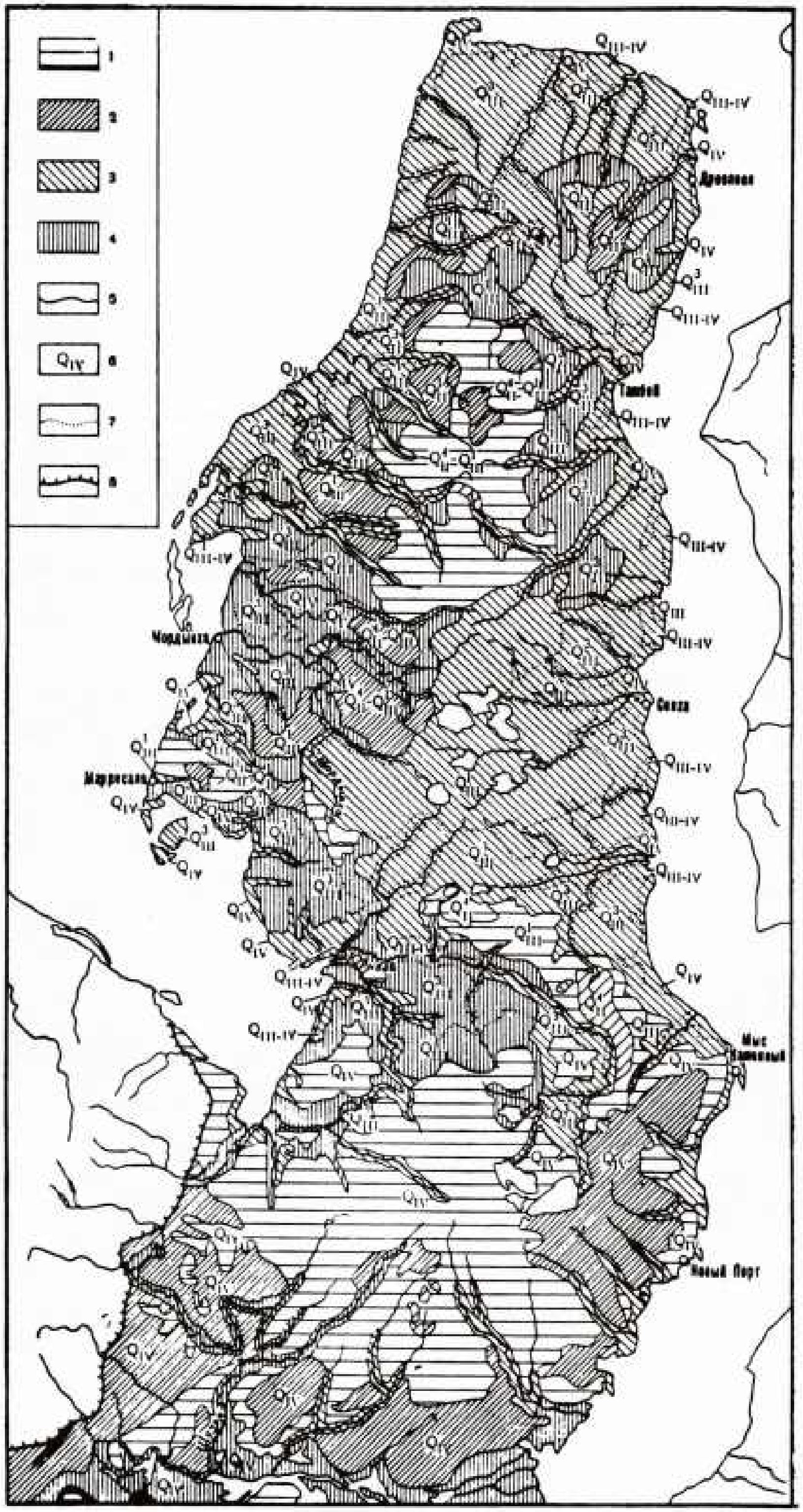

Figure A1b. Distribution of genetic types and ice content of the top 10 meters of ground on the Yamal Peninsula. (From Badu and Trofimov 1974.)

Legend - Figure A1b

1 - icy, epigenetic frozen rock (moisture content of the combined soils is below the upper plasticity level, arenaceous rock - below full moisture capacity);

2 - high-ice-content epigenetic frozen rock (moisture content of the combined soils is above the upper plasticity level, arenaceous rock - above full moisture capacity);

3 - high-ice-content syngenetic frozen rock;

4 - terrain with primarily high ice content, top 3-6 m of the cross section is syngenetic frozen rock, underlain by epigenetic frozen rock;

5 - boundaries of regions, composed of permafrost of different genesis or unequal ice content;

6 - age of permafrost;

7 - boundaries of permafrost of various age;

8 - boundary of exposed surficial Paleozoic rock of the Urals.

Table A1. Summary of volume ice content of syngenetic frozen ground of the Yamal Peninsula.

Genesis and ground age	Ground makeup	Ice content volume (%)	Cryogenic texture
	Fine-grained sand	25-35	Massive
$mQ^{1}III$	Fine-grained, peat-formed sand	35-50	Massive, rarely layered
	Sand with layers of sandy silty	40-50	Layered
	Loam and clayey silty loam		
$mlQ^{2-3}III$	Fine-grained sand	35-40	Massive
	Peaty sand with layers of sandy	42-60	Rarely layered, massive
	Silty loam and clayey silty loam		
$mQ^{2-3}III$	Sandy silty loam	40-45	Layered
	Clayey silty loam	40-50	Layered, reticulated
	Clayey silty loam	50-60	Recticulated, layered
$mlQ^{3-4}III$	Fine-grained sand with layers of sandy silty loam	40-50	Massive
$mQ^{3-4}III$	Clayey silty loam	34-40	Layered
	Clayey silty loam	55-58	Layered, reticulated
mlQIII-IV	Fine-grained sand	33-42	Massive
mQIII-IV	Clayey silty loam	48-55	Layered, reticulated
mlQIV	Fine-grained sand	35-40	Massive
mQIV	Fine-grained sand with layers of sandy silty loam	45-50	Massive
	Sandy silty loam with layers of clayey silty loam	55-70	Layered, reticulated
	Clayey silty loam with layers of sand	50-60	Reticulated
aQIV	Fine-grained sand	30-36	Massive
	Fine-grained, peat-formed sand	36-45	Massive
	Sandy with layers of sandy silty loam	40-50	Layered
	Sand with layers of clayey silty loam, peat formed	45-55	Layered
	Sandy silty loam	40-45	Layered
	Sandy silty loam	50-60	Layered
	Clayey silty loam	50-70	Layered

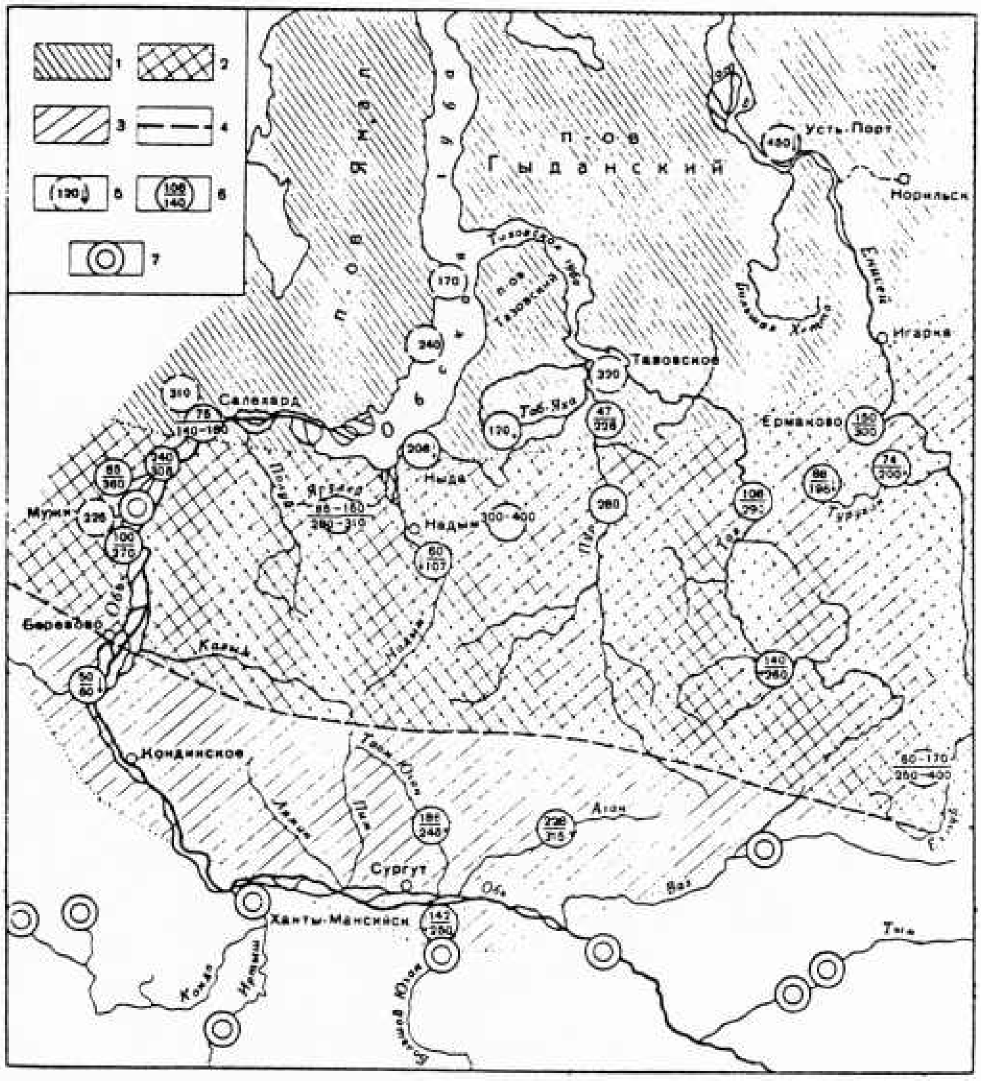

Figure A2. Permafrost distribution in the northern part of the western Siberian lowland. The map was compiled with data obtained up to 1961. (From Baulin 1962.)

Legend - Figure A2

1 - district of primarily continuous (by depth) distribution of permafrost;

2 - district of primarily two-layered permafrost structure;

3 - district of deep permafrost; top is 200 m or more below ground surface;

4 - boundary of upper layer of permafrost;

5 - boreholes and groups of boreholes exposing permafrost; circled number is depth (m) to which the permafrost extends (arrows indicate that the bottom was not located);

6 - boreholes and groups of boreholes exposing the second layer of permafrost. Numerator - depth (m) to the top of second layer of permafrost. Denominator - depth (m) to which permafrost extends.

7 - boreholes and groups of boreholes not exposing permafrost.

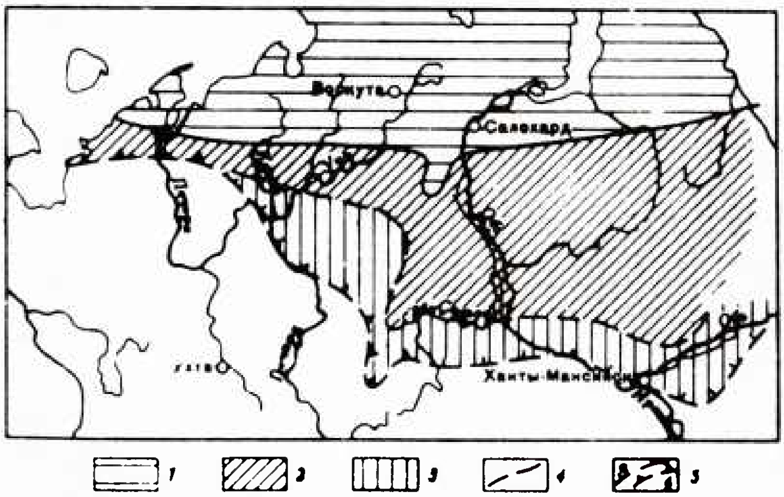

Figure A3. Permafrost distribution in the north-east European part of the USSR. (From Baulin et al. 1978.)

Legend - Figure A3

1 - zone of primarily continuous vertical-structure permafrost;

2 - zone of primarily two-layered permafrost;

3 - zone of relic permafrost;

4 - southern boundary of distribution of exposed frozen rock in mineral soils;

5 - southern boundary of distribution of relic permafrost (a) established, b) supposed).

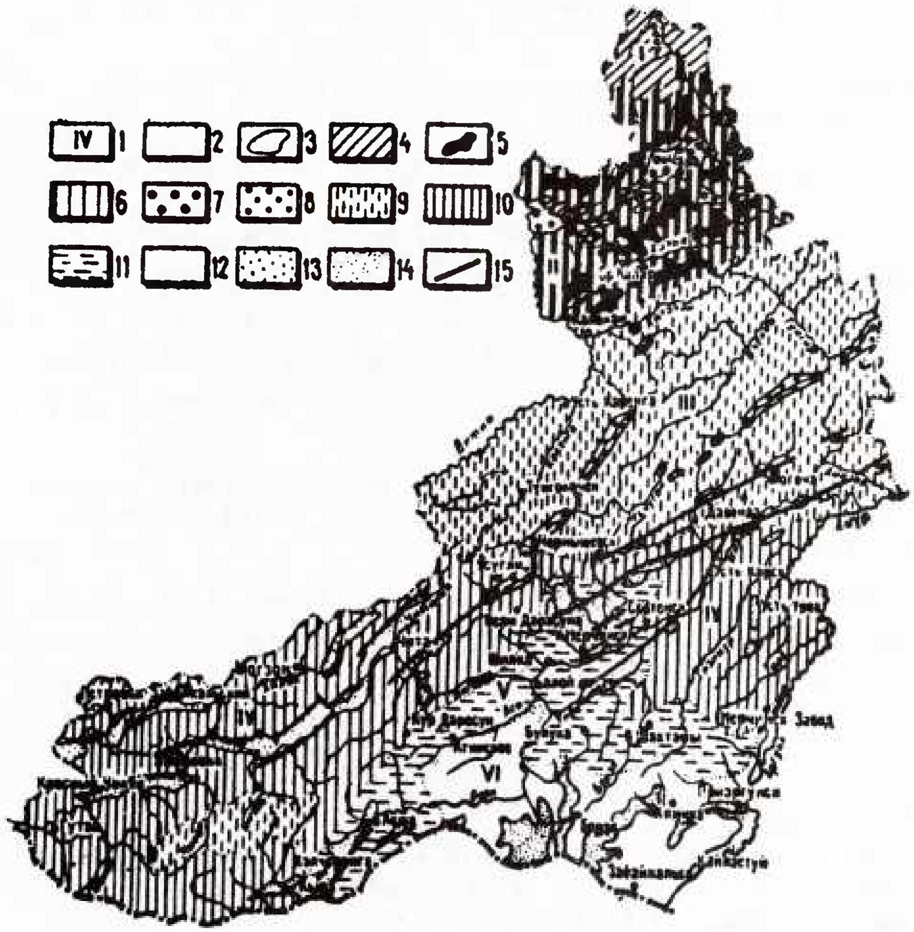

Figure A4. Permafrost distribution in the Zabaikal area (in the Chitinskoy province). (From Bogomolov et al. 1972.)

Legend - Figure A4

1 - numbers of geocryological regions;

2 - boundaries of geocryological regions;

3 - boundaries between permafrost of differing thickness and temperature;

4 - permafrost with thickness to 100 m, rarely to 250-300 m with temperature at the underseam of the layer varying annually from 0°to -5°C.

Plateau of the Siberian Platform:

5 - the same, thickness from 500 to 1000 m and temperature from -5° to -10°C. Central part of alpine mountain structure;

6 - the same, thickness from 300 to 500 m with temperature from -3° to -9.5°C. Central and edge parts of alpine mountain structure;

7 - the same, thickness from 100 to 300 m with temperature from -1° to -3.5°C. Baikal-type depressions;

8 - the same, thickness to 100 m, maximum 200 m, with temperatures from 0° to -2.5°C. Baikal-type depressions, small inter-montane Baikal-type depressions;

9 - the same, thickness 100 to 300 m with temperature -1° to -5.5°C.

Mountain unfrozen regions of the Olekma River and Vitima River basins.
High mountain and bare peak regions of central Zabaikal (far Baikal);

10 - the same, thickness to 50 m with temperature -1° to -3°C Montaine-talik regions of Central and Eastern Zabaikal;

11 - the same, thickness to 30 m with temperature from -1.5° to -2.5°C;

12 - the same, thickness to 20 to 30 m, maximum 50 to 100 m with temperature from -0.2° to -2.5°C. Depressions of Zabaikal and Mongolian types. Steppe and Forest-steppe expanses;

13 - the same, thickness to 10 m, maximum to 20 m, with temperature from -0.1° to -1°C;

14 - the same, thickness to 10 to 20 m, maximum 30 to 40 m with temperature from -0.1° to -0.2°C. Depressions of Zabaikal and Mongolian types. Steppe expanses;

15 - Faults.

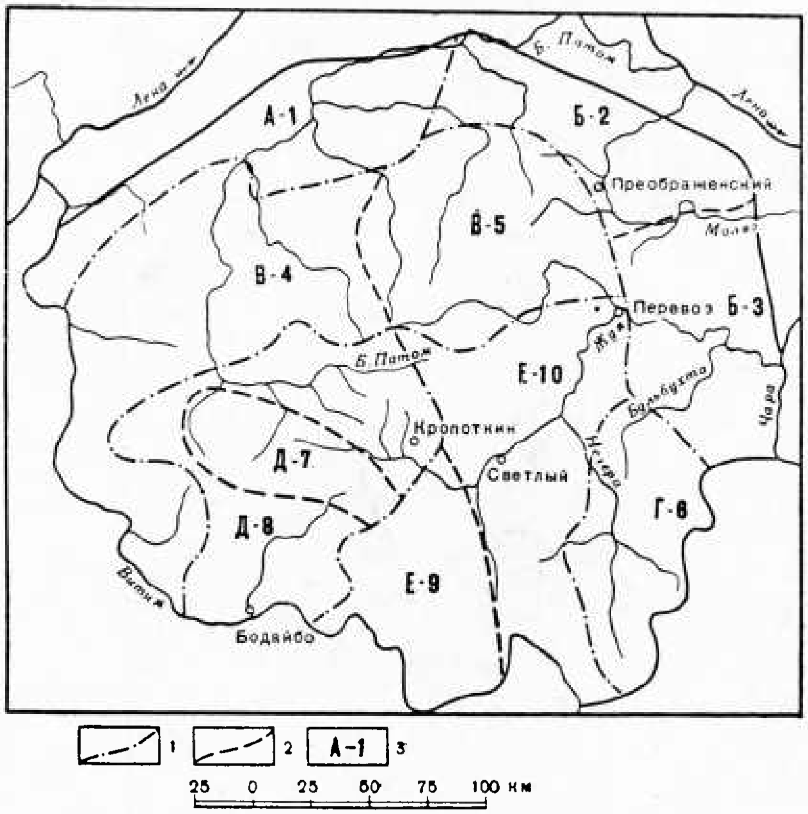

Figure A5. Permafrost-temperature divisions of the Patomski foothills. (From Boiarskii et al. 1968.)

Legend - Figure A5

1 - boundary of permafrost-geological area;

2 - boundary of permafrost-temperature region;

3 - index of areas and regions (see Table A5 for descriptions).

Table A5. Characteristics of permafrost of Patomski foothills.

Area number	Permafrost character	Average annual temperature (°C)
A-1	discontinuous permafrost characteristic water divide and valley taliks	water divides +0.5 to -2.0
Б-2	continuous permafrost through taliks and "pseudo taliks" under rivers and in Karsted Valley areas	water divides -2.0 to -4.0 valleys 3.0 to 5.0
Б-3	same	water divides -3.0 to -5.0 valleys below -5.0
B-4	continuous permafrost through taliks in rejuvinated tectonic disturbance zones	water divides -2.0 to -3.0
B-5	same	water divides -3.0 to -5.0
Г-6	same	water divides below -5.0
Д-7	discontinuous permafrost through taliks in valleys and water divides	water divides 0.0 to -3.0
Д-8	same	water divides +0.5 to -2.0 valleys 0.0 to -2.0
E-9	continuous permafrost through taliks and "pseudo taliks" in valleys	water divides -2.0 to -5.0 valleys 0.0 to -2.0
E-10	same	water divides to -5.0 valleys -3.0 to -5.0

Figure A6. Geological and permafrost phenomena in southern Yakutia. (From Chizhov et al. 1978.)

Legend - Figure A6

1-6 Formations, geological genetic rock complexes

1 - metamorphic and intrusive (gneiss, crystal shales, granites) AR;

2 - carbonaceous (dolomites, marls, limestones) ε_1;

3 - terrigenous (sandstones, aleurites, argillites, coals) I_3-K;

4 - intrusive (syenite-porphyries, porphyries);

5 - alluvial complexes (sandy silty loams*, sands, clayey silty loams+) Q_{II-III};

6 - complexes of lake-swamp deposits (peatlands) Q_{IV};

7-11 Permafrost

7 - island distribution, t_{avg} 0° to -0.5°C, thickness to 50 m;

8 - massive island, t_{avg} -0.5° to -1°C, thickness to 100 m;

9 - discontinuous, t_{avg} -1° to -2°C, thickness to 200 m;

10 - continuous, t_{avg} -1° to -3°C, thickness 100 to 300 m;

11 - continuous, t_{avg} -3° to -5°C, thickness 200 to 500 m;

12-21 Geological and permafrost phenomena

12 - ancient karst cavities;

13 - karst;

14 - a) taluses, б) rock glaciers;

15 - wedge ice;

16 - frost mounds;

17 - thermokarst;

18 - icing of groundwater;

19 - landslides;

20 - solifluction;

21 - avalanches;

22,23 Engineering-geological processes and phenomena stimulated or activated by construction (shown in circles with the most widespread regions of active processes);

22 - gully erosion;

23 - thermal erosion;

24-26 Other symbols

24 - geological boundaries;

25 - fault lines;

26 - a) borders of regions, б) borders of regions coinciding with faults

Division into regions

А) Aldanskoye high plateau

Б) Timptono-Uchurskoye highlands

В) Central-Aldanskoye region

Г) Chulmanskoye plateau

Д) Prialdanskoye plateau

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*The Russian term for sandy silty loam is supes. It contains 3-10% clay size by weight with particles less than 0.005 mm.

+The Russian term for clayey silty loam is suglinok. It contains 10-30% clay size by weight with particles less than 0.005 mm.

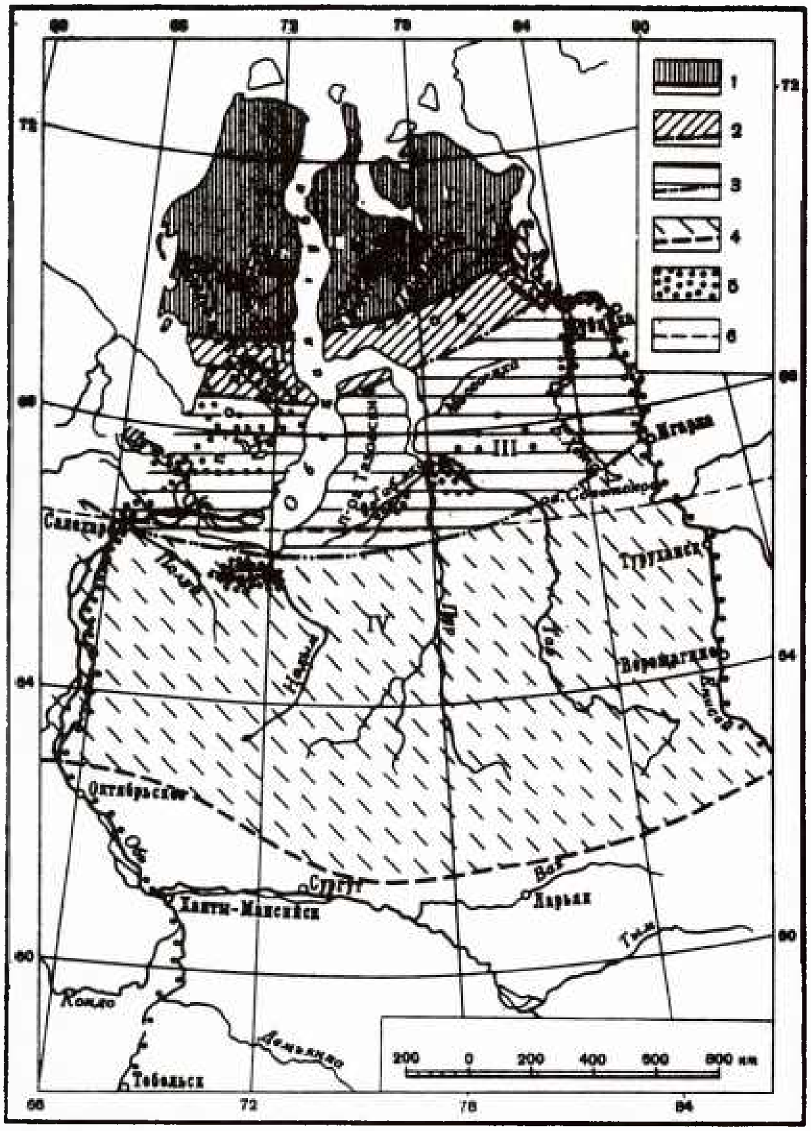


Figure A7. Distribution of genetic types of wedge ice in western Siberia. (From Dubikov 1966.)

Legend - Figure A7

1 - zone of aggrading relic syngenetic and epigenetic wedge ice in mineral soils;

2 - zone of relic syngenetic wedge ice in mineral soils, aggrading syngenetic in peatland and epigenetic in mineral soils and peatland;

3 - zone of aggrading syngenetic and epigenetic wedge ice in peatland;

4 - zone of relic wedge ice in peatland and evidence of their existence;

5 - region of operation of the western Siberian expedition of the Institute on Permafrost (1960-1964) according to V.A. Obrychev;

6 - southern border of distribution of permafrost in western Siberia according to E.B. Belopyxov.

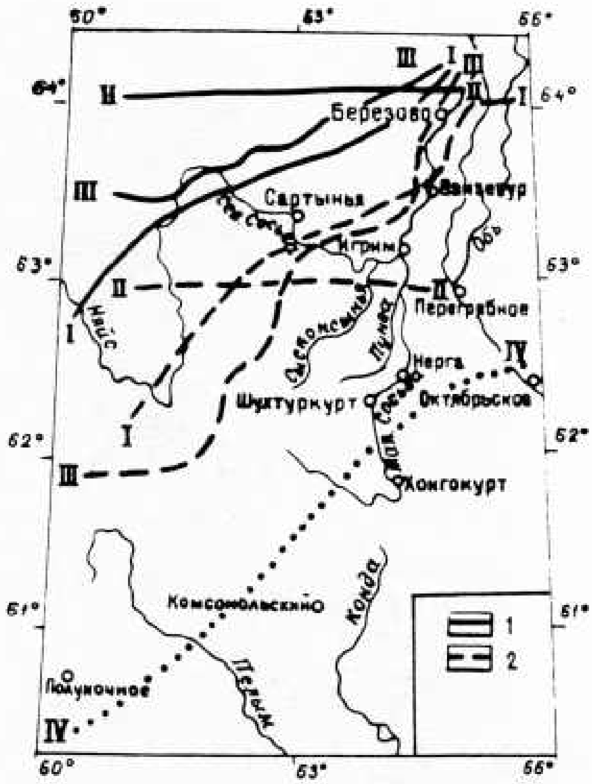


Figure A8. Position of the southern permafrost boundaries between the Urals and the Ob River. (From Dubikov 1980.)

Legend - Figure A8.

1 - mineral, 2 - organic

I - according to L.F. Kunitsyn;

II - according to E.B. Belopukhova;

III - according to A.I. Popov and N.A. Shpolyanskaya;

IV - boundary proposed by author.

Figure A9. Distribution of injected fossil ice on the Yamal Peninsula. (From Dubikov and Kopeysha 1964.) 1 -individual deposits of ice; 2 - region where many ice deposits are located.

Figure A10. Engineering-geological division of the northeastern Siberian platform. (From Golodkovskaia and Ivanov 1970.)

Legend - Figure A10

Western Siberian (Pri-yeniseyski region):

1 - area of Pri-yeniseyski upper Quaternary glacial-marine plain;

Hantaysko-Dusinski region:

2 - area of Hantaysko-Dudinski glacial-marine upper Quaternary plain;

Norilski region:

3 - area of Fokinsko-Pyasinsko glacial-marine upper Quaternary plain;

4 - area of Norilsko Neogene-Quaternary structural denudation plateau;

Hantaisko-Rybninski region:

5 - area of Norilsko upper Quaternary glacial-marine erosion-accumulated submontane plain;

6 - area of Hantaisko-Ribninsko upper Quaternary glacial-marine intermontane plain;

Tunrusski region:

7 - area of Haraelahskogo Neogene-Quaternary structure denudation plateau.

Genesis, age, makeup of ground:

8 - alluvial contemporary deposits: fine-grained clayey silty loams, sandy silty loams, gravels. Ground medium and high ice content;

9 - lake alluvial deposits. Primarily banded clayey silty loams, rarer heavily iced clays;

10 - lake alluvial deposits. Primarily clays. Rarer clayey and sandy silty loams, high ice content with horizontal layering;

11 - lagoon and shore-marine deposits. Clays, clayey silty loams, sands with gravel, medium and high ice content;

12 - glacial-marine deposits. Interbedded with cobbled clayey silty loams, sandy silty loams, gravels and sand. Medium ice content;

13 - glacial deposits: cobbled clayey silty loams, sandy silty loams,

14 - alluvial and alluvial-solifluction contemporary deposits: large rock-debris, rock debris accumulation, with insignificant filler; low ice content;

15 - lake-swamp contemporary deposits: turf, clayey and sandy silty loam; high ice content;

16 - boundaries of engineering-geological regions;

17 - boundaries of engineering-geological areas;

18 - boundaries of engineering-geological zones;

19 - boundaries of engineering-geological subzones;

20 - numbers of engineering-geological zones.

Subzones	Permafrost Thickness	Temperature
a	0 to 20 m	0° to -0.5°C
Б	20 to 50 m	-0.1° to -1.0°C
B	50 to 100 m	-1° to -3°C
Г	100 to 200 m	-3° to -5°C
Д	200 to 400 m	-5° to -7°C
e	>400 m	<-7°C

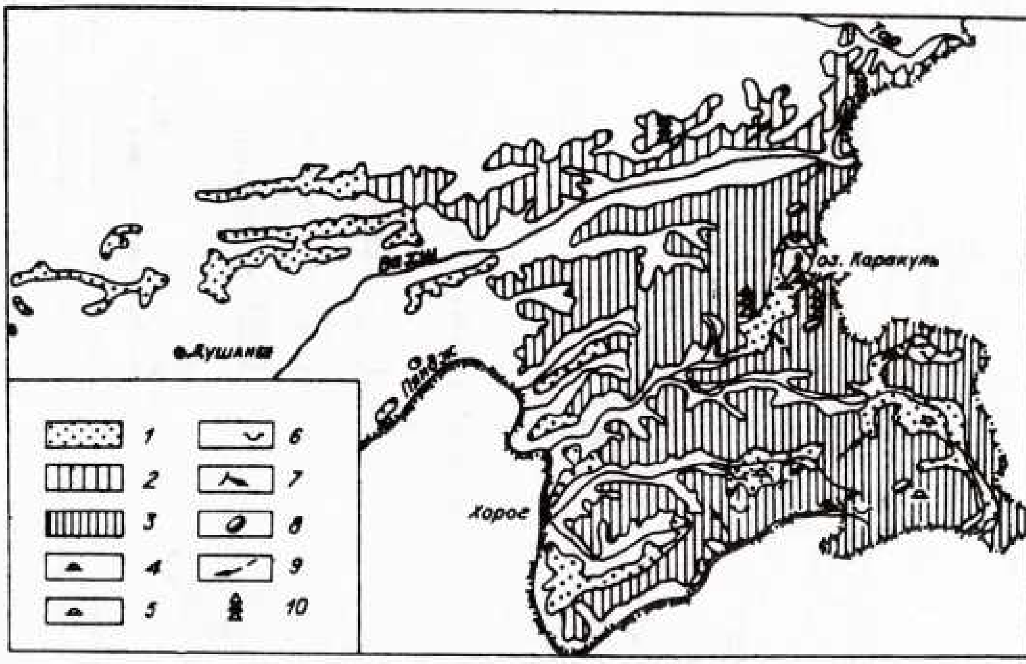


Figure All. Cryogenic phenomena of the Pamir Alai Mountains (scale 1:6,000,000). (From Gorbunov 1978.)

Legend - Figure All

Types and distribution of permafrost:

1 - primarily island;

2 - primarily discontinuous;

3 - primarily continuous.

Cryogenic forms of relief:

4 - perennial hydrolaccoliths (pingos);

5 - seasonal hydrolaccoliths (frost mounds);

6 - thermokarst subsidence;

7 - ledges induced by thermal erosion;

8 - large-scale icing and annual icing sites;

9 - large-scale solifluction features;

10 - rock glaciers.

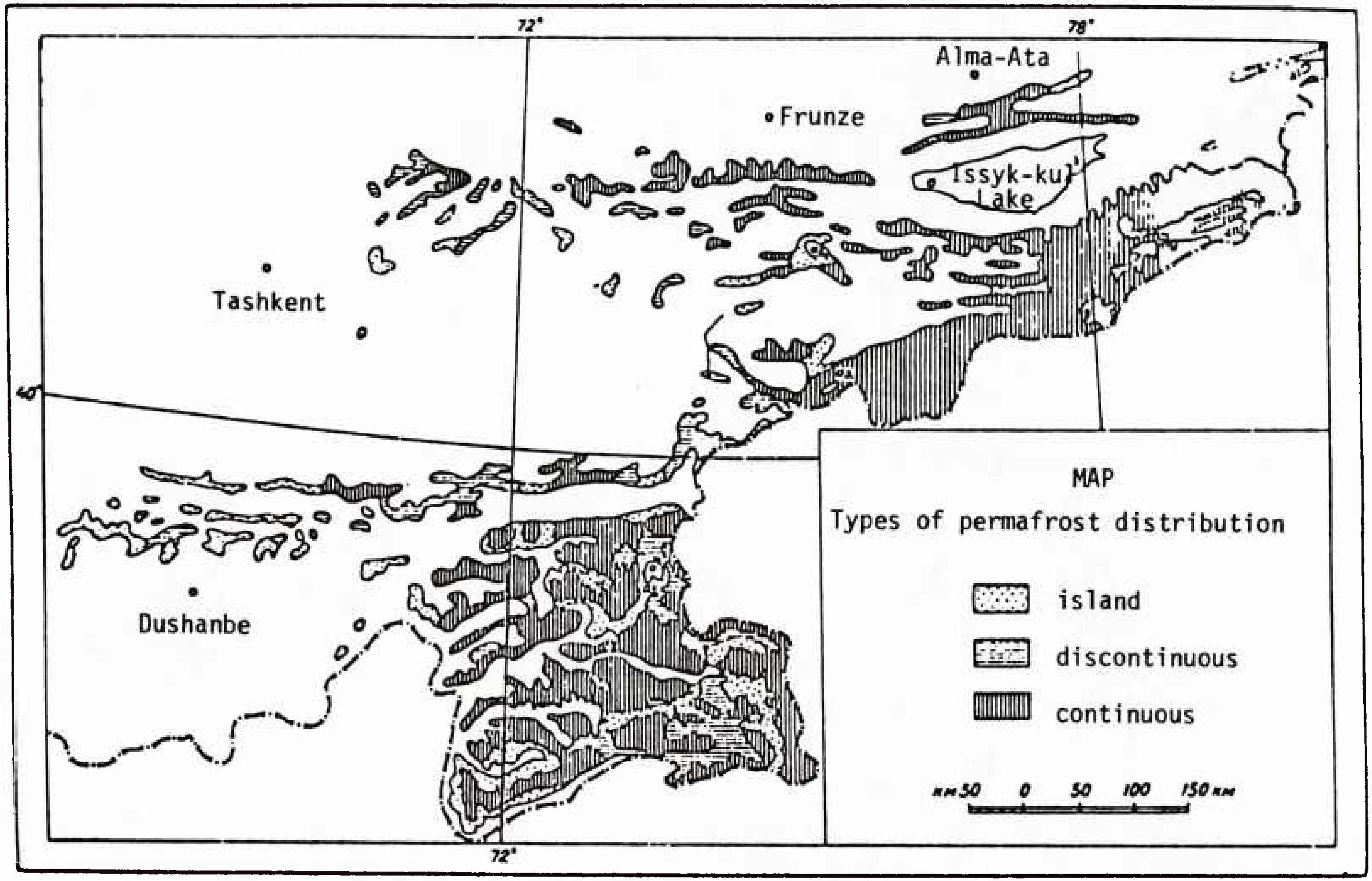


Figure A12. Permafrost distribution in the mountains of central Asia. (From Gorbunov 1980.)

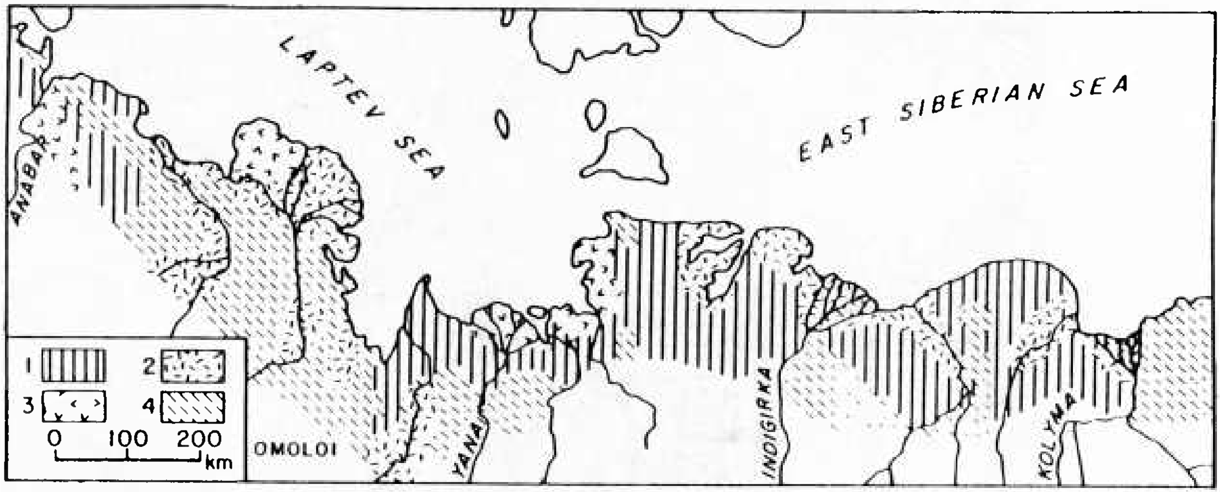


Figure A13. Distribution of dispersed deposits with different ice saturation in the coastal zone of Yakutia. (From Grigor'iev 1966.)

Legend - Figure A13

1 - regions with primary development of ancient thick secondary vein ice associated with remnants of ancient alluvial plains (of ice veins up to 6-8 m in width and up to 40-45 m in height);

2 - regions with primary distribution of intermediate density of network of ice veins associated with floodplains and alassy (of ice veins up to 2-3 m in width and up to 10-12 m in height);

3 - regions with primary distribution of thin network of thin secondary vein ice associated with remnants of sandy coastal marine plain (ice veins up to 1-2 m in width and up to 3-5 m in height);

4 - regions with primary distribution of bedrock outcrops.

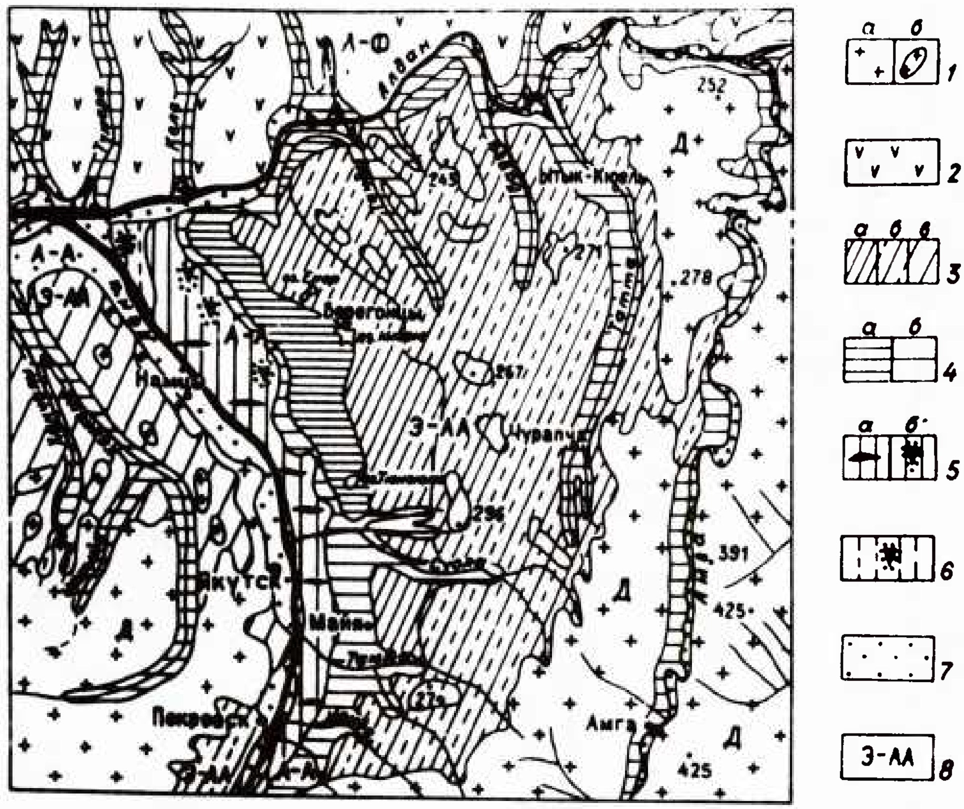


Figure A14. Ground ice distribution in the eastern part of central Yakutia. (From Ivanov 1980.)

Legend - Figure A14

1 - <u>Denudation plain</u>

a) Underground ice composed of ground ice and sporadically distributed wedge ice on denudation accumulated gentle slopes; depth of occurrence of wedge ice varies from 1-1.4 m in damp peaty plots to 1.5-3 m in forested and partial steppe areas; wedge ice of width 1 to 3 m, height from 2-3 to 10-17 m developed in clayey silty loam, sandy silty loam with bands of fine-grained sand, filling the complex regions of the upper reaches of small rivers, in sandy silty loam and sandy deposits of separate patelloid (saucer-shaped) depressions, in clayey silty loam and sandy silty loam with bands of sand of above-floodplain terraces of small rivers, in clayey silty loams, sandy silty loams and very fine sands of debris cones;

Б) Drainage of interstream rises, plots and outliers of pre-Quaternary formation covered by sandy silty loams and very fine sands without wedge ice

2 - <u>Accumulative Glacial-Fluvioglacial Plain</u>

Ground ice composed of pervasive ground ice and wedge ice developed in clayey-sandy-silty loam and sandy deposits of above floodplain terraces of rivers, depressions between sea hillocks, likewise injected and possibly glacier-buried ice; depth of occurrence of wedge ice varies from 0.8 to 1.2 m on swampy and peaty depressions to 1.5 to 3.5 m on dry drained plots. Width of ice wedges varies from 1.5-3 to 5-7 m, heights up to 12-15 m. Depth of occurrence of ice sheets 10-12 m, thickness to 10 m, diameters - 100 m.

3 - Erosion- Accumulated Abalahskaya Plain

Ground and wedge ice widely developed on all elements of macro-, mezo- and micro-relief;

a) Zone of jointed tectonic ledge Abalahskaya plain, made up of clayey-silty loam, sandy-silty loam and bands of fine-grained sand with the heightened thickness of ice complexes; width of ice wedges 2-6 m, vertical thickness from 30-40 m in the extreme southern part to 60 to 75 m and more in the central and northern parts of the jointed zone. Depth of occurrence of ice wedges varies from 1.2-1.8 to 2.5-3 m;

Б) Areas of wide development of wedge ice in clayey-silty loam and sandy-silty loam of the erosion-accumulated plain; width of ice wedges varies from 2-3 to 5-7 m, height from 15-25 to 40-50 m, depth of occurrence of ice along the jointed zone with denudation plain varies from 0.8-1.2 m to 0.5-3 m, in the other parts of the area from 1.5-2 to 2.5-3 m.

B) Areas of sporadic distribution of thin wedge ice, developed in clayey-sandy silty loam and sandy deposits in the valleys of small rivers, erosional areas, creeks, drainage hollows and in clayey-sandy silty loam slope deposits overlapping flat water-dividing outliers of pre-Quaternary development, width of ice wedges varies from 1-2 to 3-5 m, height from 5-6 to 15-20 m; depth of deposit of wedge ice depending on the landscape conditions varies from 1.5 to 4 m.

4-7 Accumulative Alluvial Plain

4 - Tungulunskaya (above floodplain) terrace of the Lena River composed of interbedded clayey silty loams, sandy silty loams sands and corresponding to it by structure above floodplain flats of the rivers Aldana, Amgi and their tributaries.

a) Areas of distribution of wedge ice with heightened (from 15-30 to 40-50 m) vertical thickness, their width from 2-3 to 4-6 m, depth of occurrence of ice varies from 1.4-2.2 m in closed, forested masses to 2.5-4 m in open, steppe areas.

Б) Areas of development of wedge ice of vertical thickness 10-25 m, width 2-3 m, depth of occurrence varies from 1.8-2.4 to 2.5-4 m.

5 - Sandy alluvial Bestiakhskoy (above floodplain) terrace of the Lena River.

a) Sheet deposits of injected and segregated ice thickness from 0.5-1 to 3-4 m, length from 5-20 to 150-200 m, depth of occurrence varies from 2.5-10 to 40-50 m.

Б) Wedge ice, developed locally in silted fine-grained sands with interlayers of sandy silty loam; width of ice 1.5-2 m, height 5-10 m, depth of occurrence of upper end of wedges varies from 3-5 to 7-8 m.

6 - Sands with interlayers of sandy silty loam of the Kerdemskoia (above floodplain) terrace of the Lena River; in places, occurrence of locally developed degrading wedge ice with pseudomorphisms in the upper parts.

7 - Low ice content sands of low terraces of Lena, Aldana, and Amgi Rivers, overlapped with a thin layer (0.6-1.2 m) of clayey and sandy silty loam; in between ridge moistened depressed sporadically developed soil-ice veins, width from 3-5 to 10-60 cm, height from 0.5-1 to 2-2.5 m.

8 - Indexes of selected types of plain: - Denudation; -Ф- Glacial-Fluvioglacial; A-A Alluvial-Accumulative: З-AA Erosion-Accumulated.

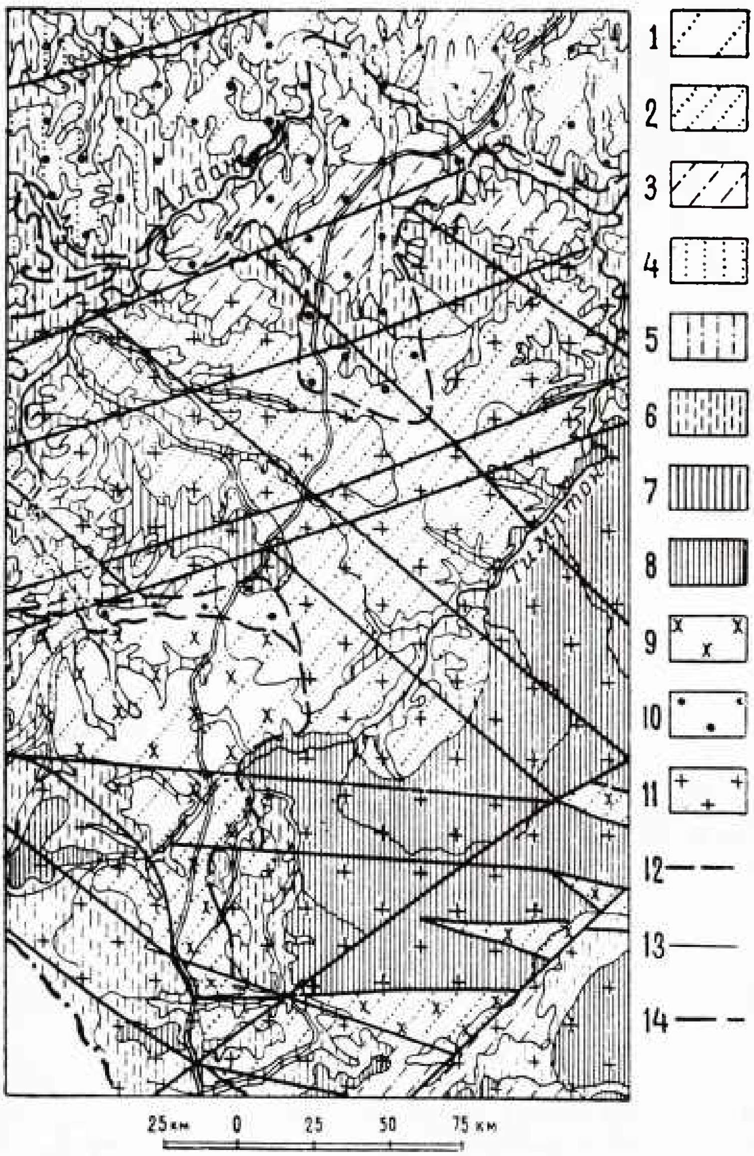


Figure A15a. Permafrost in the central part of southern Yakutia. (From Kondrat'eva 1966.)

Legend - Figure A15a

Types of permafrost: alluvial-cemented with ice; rooted with ice by cracks to depths of 100 m:

Island distribution:

1 - thickness to 50 m, t_{avg} from 0° to -1°C;

2 - thickness to 100 m, t_{avg} from 0° to -1°C;

3 - thickness to 100 m, t_{avg} from -1° to -2°C;

Continuous distribution:

4 - thickness to 100 m, t_{avg} from 0° to -1°C;

5 - thickness to 100 m, t_{avg} from -1° to -2°C;

6 - thickness to 300 m, t_{avg} from -2° to -3°C;

7 - thickness to 300 m, t_{avg} <-3°;

8 - thickness > 300 m, t_{avg} <-3°;

Lithological makeup of root soils:

9 - sandstones, aleurites, argillites with layers of coal, Jurassic period;

10 - dolomites, limestones with layers of marls, early Cambrian period;

11 - granite-formed crystallized shales and gneisses of the Archean complex, shales and gneisses of the Proterozoic complex;

12 - geological boundaries;

13 - permafrost type boundaries;

14 - zones of regional fractures.

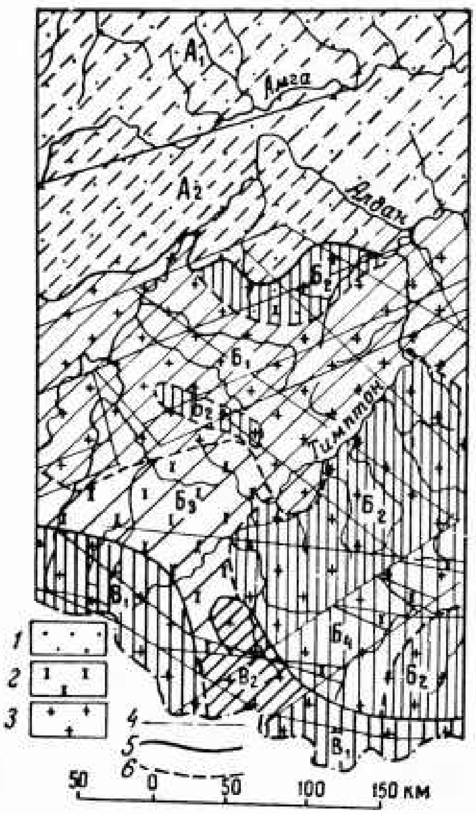


Figure A15b. Permafrost division of the central part of southern Yakutia. (From Kondrat'eva 1966.)

Legend - Figure A15b

A - formation of high, medium, and low height plateaus of the Siberian platform with fine-grained deposits of the Cambrian and Jurassic with absolute heights of 400 to 800 m;

A_1 - permafrost distribution: island: unfrozen water divides (t_{avg} from 0° to +2°C), frozen valleys (t_{avg} from 0° to -2°C, permafrost thickness to 100 m);

A_2 - permafrost distribution: island: low (400 to 650 m) unfrozen water divides (t_{avg} from 0° to +1°C), high water divides, bare peaks (1200 to 1600 m) and frozen valleys (t_{avg} from 0° to -3°C, thickness to 300 m);

Б - formation of foothills of the Siberian platform on metamorphic Archean and sedimentary Cambrian and Jurassic types with absolute heights 800 to 1700 m;

$Б_1$ - permafrost distribution: island on low water divides (t_{avg} from +1° to -1°C, thickness 50 to 100 m); continuous in valleys and on high water divides (t_{avg} from 0° to -3°C; thickness to 200, rarer 300 m);

$Б_2$ - permafrost distribution: continuous (t_{avg} 0° to -3°C, rarer <-3°C; thickness to 300, rarer >300 m);

$Б_3$ - permafrost distribution: island, water divides unfrozen, (t_{avg} from 0° to +2°C); valleys frozen (t_{avg} from 0° to -1°C rarer to -2°C, thickness to 100 m);

$Б_4$ - permafrost distribution: continuous on high plateaus and bare peaks (t_{avg} from 0° to -3, -4°C, thickness >300 m); island on low plateaus (t_{avg} from +1° to -1°C, thickness to 100 to 200 m);

B - formation of mountain ranges of Baikal folding belt, composed of Archean and Proterozoic metamorphic types with absolute heights 1400 to 2000 m;

B_1 - permafrost distribution: continuous (t_{avg} 0° to -4°C, thickness >300 m);

B_2 - permafrost distribution: island (t_{avg} from +1° to -1°C, thickness to 200 m);

1 - dolomites and limestones with interlayers of marls of lower Cambrian age;

2 - sandstones, alleurites, argillites with interlayers of coal of the Jurassic age;

3 - granitoid crystallized shales and gneisses of the Archean complex and diaphthorized shales and gneiss of the Proterozoic complex;

4 - zones of regional explosive disturbances, flooded in places of crossing of waterways and on flat water divides;

5 - boundaries of frozen-geological formations;

6 - boundaries of frozen-geological subformations.

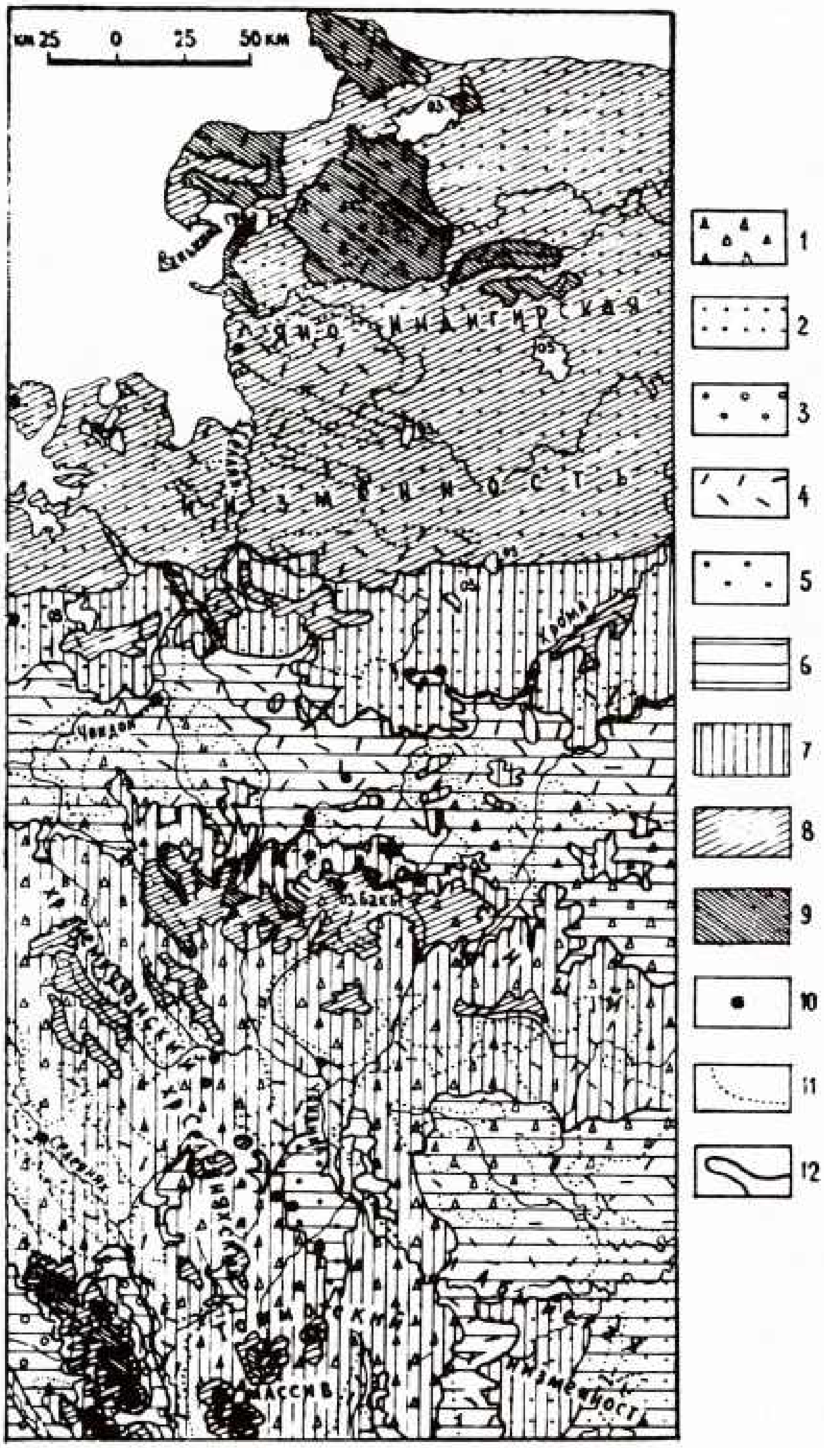


Figure A16. Average annual ground temperatures in the Iana-Indigirka interfluve. (From Kondrat'eva et al. 1972.)

Legend - Figure A16

Geologic-genetic ground complexes:

1 - recent slope deposits on Mesozoic terrigenous, Paleozoic carbonaceous, Proterozoic terrigeno-carbonaceous and erupted types of the Cretaceous period (c,d,s QIV);

2 - primarily contemporary and upper Quaternary alluvial and lake-swamp depoists (al, lh QIII-IV);

3 - upper Quaternary glacial and fluvio-glacial deposits (gl, fgl QIII);

4 - primarily mid and upper Quaternary lake-alluvial deposits (lal QII-III);

5 - Neogene-lower Quaternary lake-alluvial deposits (lal N-Q1);

Zones of average annual ground temperatures (°C):

6 - from -5° to -7°;

7 - from -7° to -9°;

8 - from -9° to -11°;

9 - from -11° to -13° or -14°;

Other symbols:

10 - areas of temperature reading in boreholes;

11 - boundaries of geologic-genetic ground complexes;

12 - boundaries of zones of average annual temperatures.

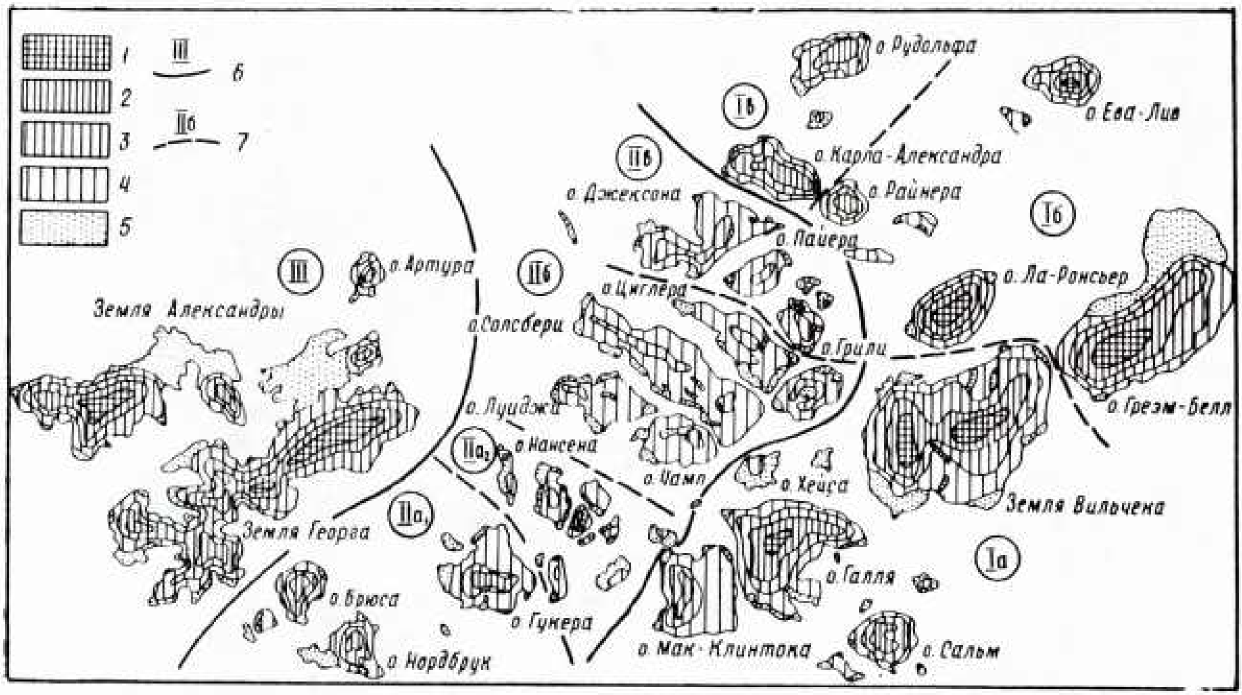


Figure A17a. Thickness of the ice cover at Franz Josef Land. (From Kondrat'eva 1980.)

Legend - Figure A17a

1 - 400 to 300 m;

2 - 300 to 200 m;

3 - 200 to 100 m;

4 - up to 100 m;

5 - ice-free land;

6 - boundaries and numbers of regions;

7 - boundaries and numbers of subregions.

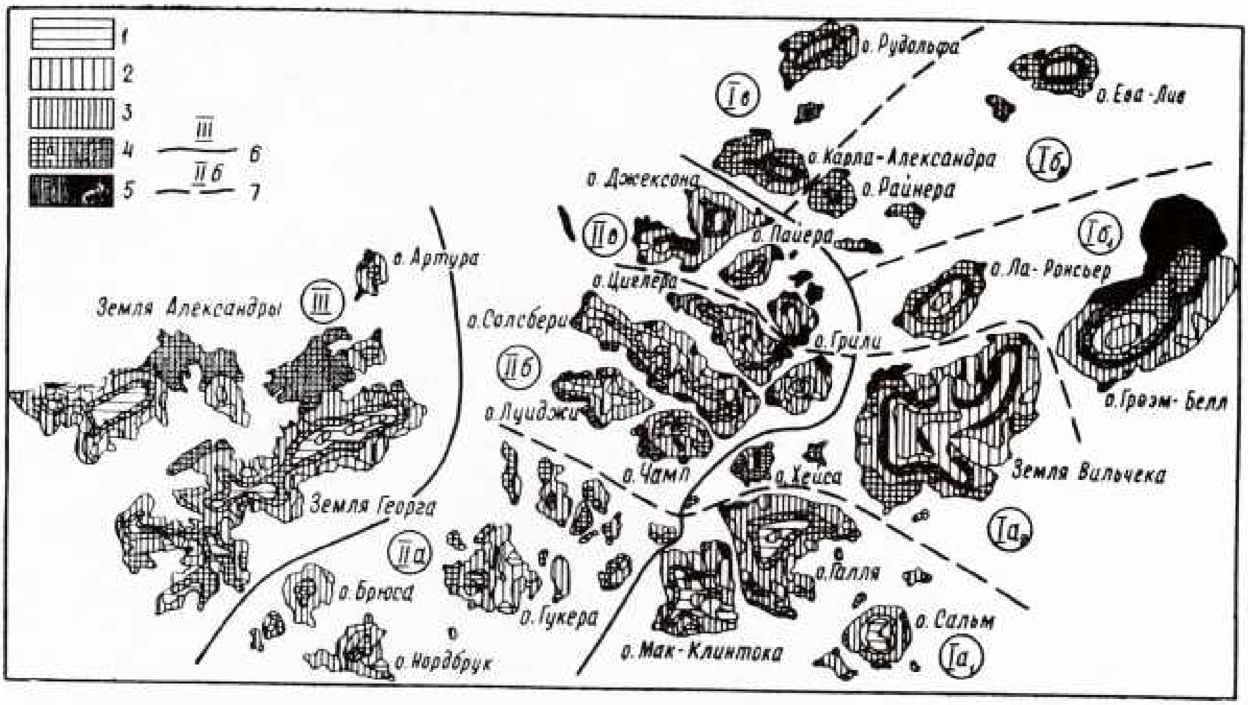


Figure A17b. Average annual ground and ice cover temperatures at Franz Josef Land. (From Kondrat'eva 1980.)

Legend - Figure A17b

1 - from -3° to -5°C;

2 - from -5° to -7°C;

3 - from -7° to -9°C;

4 - from -9° to -11°C;

5 - from -11° to -13°C;

6 - boundaries and numbers of regions;

7 - boundaries and numbers of subregions.

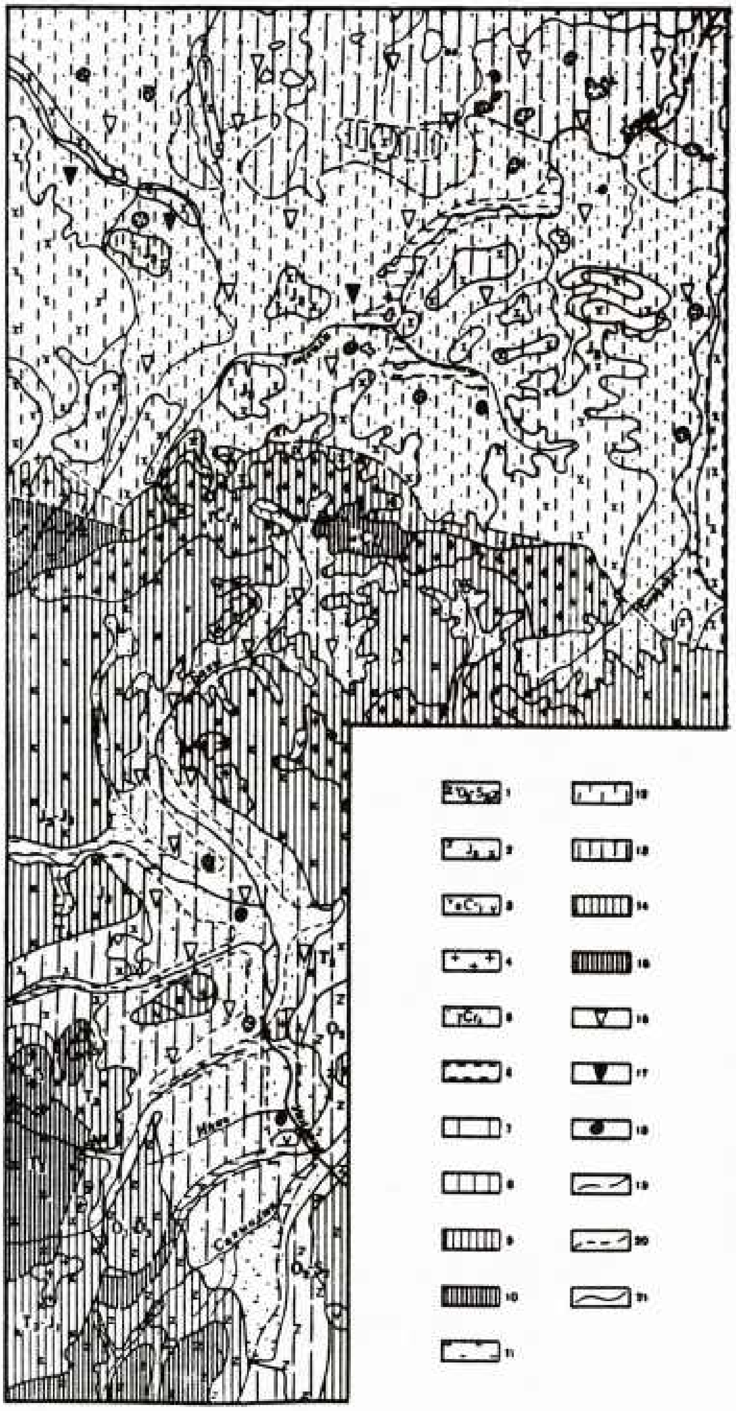


Figure A18a. Permafrost and age and composition of rock in the Iana-Indigirka depression. (From Kudriavtsev et al. 1973.)

Legend - Figure A18a

Age and composition of rock:

1 - Paleozoic limestone, dolomite, shales and others;

2 - Mesozoic sandstones, shales, argillites and others;

3 - Early Cretaceous extrusions;

4 - Early Cretaceous intrusions;

5 - Cenozoic gravels, partly covered by peat-forming clayey silty loams and sandy silty loam (aleurites).

Thickness of permafrost:

6 - <200 m;

7 - 200-300 m;

8 - 300-400 m;

9 - 400-500 m;

10 - >500 m.

Average annual temperature (°C) of rock:

11 - -3° to -5°;

12 - -5° to -7°;

13 - -7° to -9°;

14 - -9° to -11°;

15 - below -11°.

Other signs:

16 - wedge ice in ancient plains;

17 - wedge ice in the flat bottom of depression with gentle slopes (alasses);

18 - thermokarst lakes;

19 - boundaries of permafrost with different mean annual temperatures;

20 - boundaries of permafrost with different thicknesses;

21 - boundaries of rock with different structural layering.

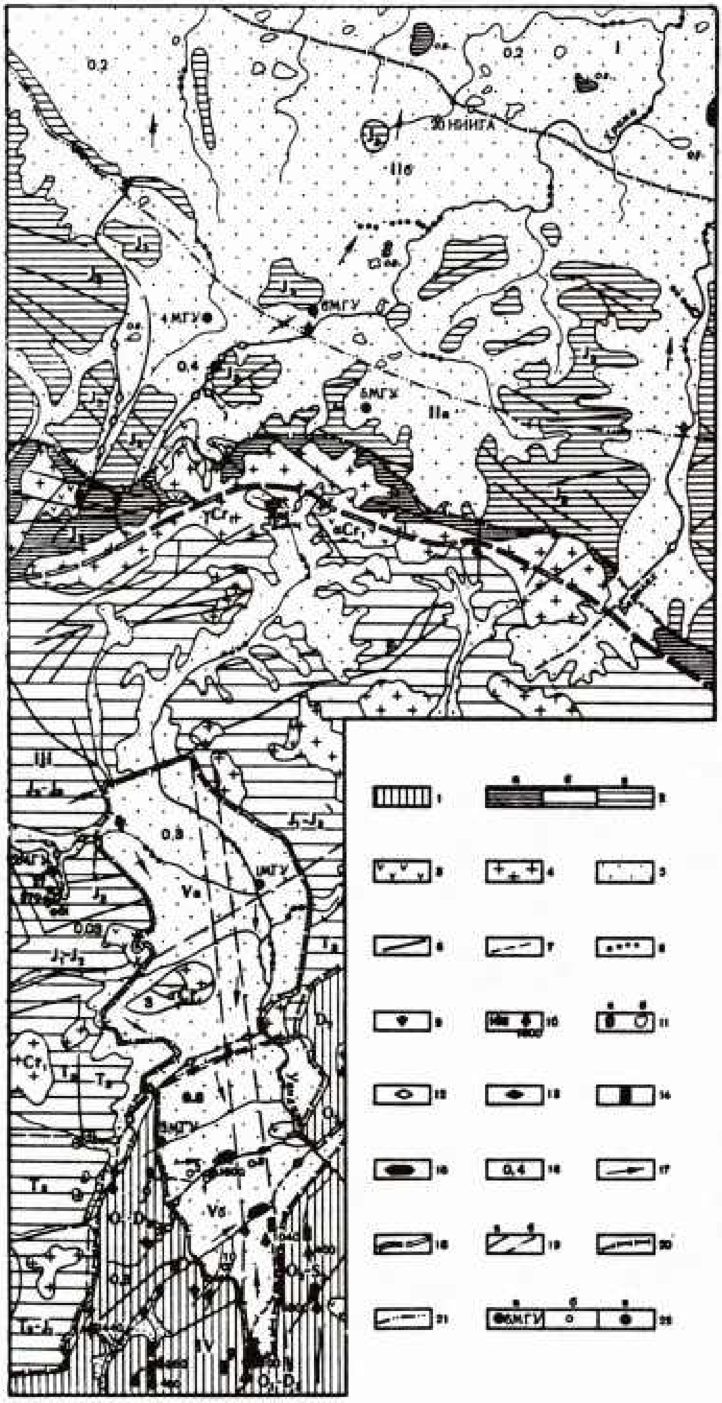


Figure A18b. Hydrogeological districts in the Iana-Indigirka depression. (From Kudriavtsev et al. 1973.)

Legend - Figure 18b

Hydrogeological cryogenic structures:

I - Littoral artesian arctic cryogenic basin with fresh, perhaps some brackish, subpermafrost water;

II - Pripolousnenski adartezianski cryogenic basin (IIa - with suprapermafrost continuously existing: with fresh water from below river bed and floodplain taliks, to a lesser degree with subpermafrost water, IIb - with subpermafrost fresh groundwater);

III - Polousnensko-Tuostakhski hydrogeological cryogenic mass with subpermafrost water of heightened mineral content;

IV - Selennyakhski hydrogeological cryogenic mass with fresh subpermafrost water and open infiltrated water, more rarely pressure-filtered talik water;

V - Uyandinski postartezianski cryogenic basin (Va - with fresh, subpermafrost water, Vb - with fresh subpermafrost water and (transitive) primarily pressure-filtered talik water);

Geological formations, taliks, icing and characteristic water content:

1 - Carbonaceous Paleozoic rock;

2 - Terrigenous rock of the Verkhoyansk complex pertaining to (a) Severo-Polousnenski system of folds, (Б) Yuzhno-Polousnenski systems of folds, (B) synclinical foothill zone;

3 - Early Cretaceous extrusions;

4 - Early Cretaceous intrusions;

5 - Cenozoic rubble deposits;

6 - Closed below-riverbed and below-floodplain ground-filtered taliks, continuously active throughout the year with an intensive character of groundwater exchange;

7 - Closed below-riverbed and below-floodplain ground-filtered taliks, periodically active during the year;

8 - Closed below-riverbed taliks with a condition of stagnant groundwater;

9 - Open below-riverbed infiltrated (inflowed) taliks;

10 - Open force-infiltrated taliks. Number at sign - spring yields in liters/sec (left - winter period, right - summer period);

11 - Below-lake taliks, a) open; Б) closed;

12 - Icing of alluvial water of closed below-riverbed and below-floodplain, periodically active taliks;

13 - Icing of mixed sources composed of below-river water and water of the deep (below permafrost) circulation of the Paleozoic water-bearing complex;

14 - Icing, made up of water of the Paleozoic water-bearing complex relieved with closed hydrogenous force-filtered taliks;

15 - Icing, one part of which has mixed sources and is confined to the valley floor, the other fed exclusively by water of deep ciruclation;

16 - Modulus of underground drainage ($L/s \cdot km^2$);

17 - Direction of flow of water of subpermafrost circulation

Other symbols:

18 - Kyton-Tasski structural seam

19 - Breaks: a) proven; Б) supposed;

20 - Boundaries of hydrogeological structures;

21 - Boundaries of areas (within hydrogeological structures) with differing characters of underground drainage;

22 - Boreholes

a) revealing subpermafrost water or talik water;

b) not permeating the entire thickness of the permafrost;

B) groups of wells, revealing subpermafrost water or talik water.

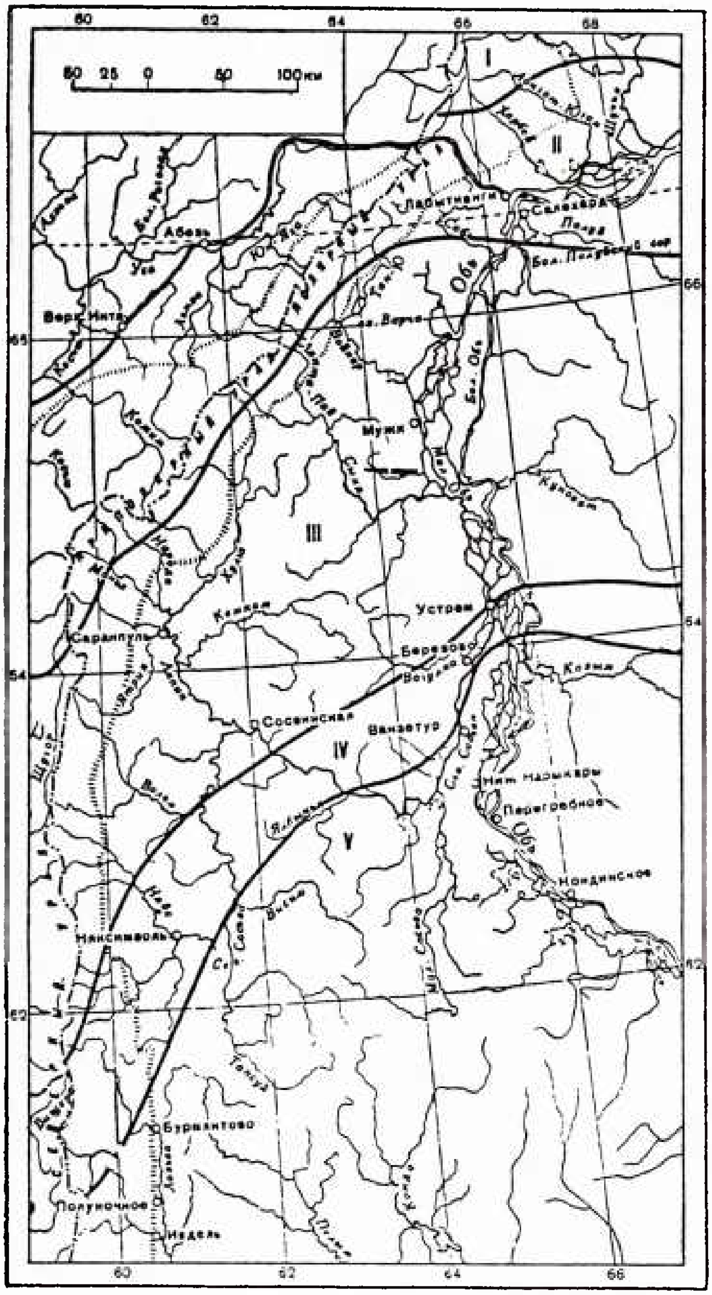


Figure A19. Distribution of permafrost in the northwestern part of the western Siberian lowland. (From Kunitsyn 1958.)

Legend - Figure A19

Northern permafrost zone

I - Tundra subzone: continuous permafrost, thickness >100 m. Temperature of frozen ground -3°C and below;

II - Forested-tundra subzone: nearly continuous permafrost, thickness 50 to 100 m. Temperature -3° to -1°C;

Southern permafrost zone

III - Northern-taiga subzone: island permafrost; developed in peat mounds and mineral soils below the taiga, often not present in sands, burned spots, notches. Thickness not greater than 15 to 20 m. Temperature close to 0°, in peat mounds to -2°C;

IV - Hillocky-peat subzone: permafrost only in frost mounds-island. Thickness not greater than 15 to 20 m. Temperature close to 0°C;

V - Subzone of spots and rare small sections of permafrost. Observed near particularly permafrost-enhancing geologic-geographic features. Probability of permafrost steadily diminishes as you move south.

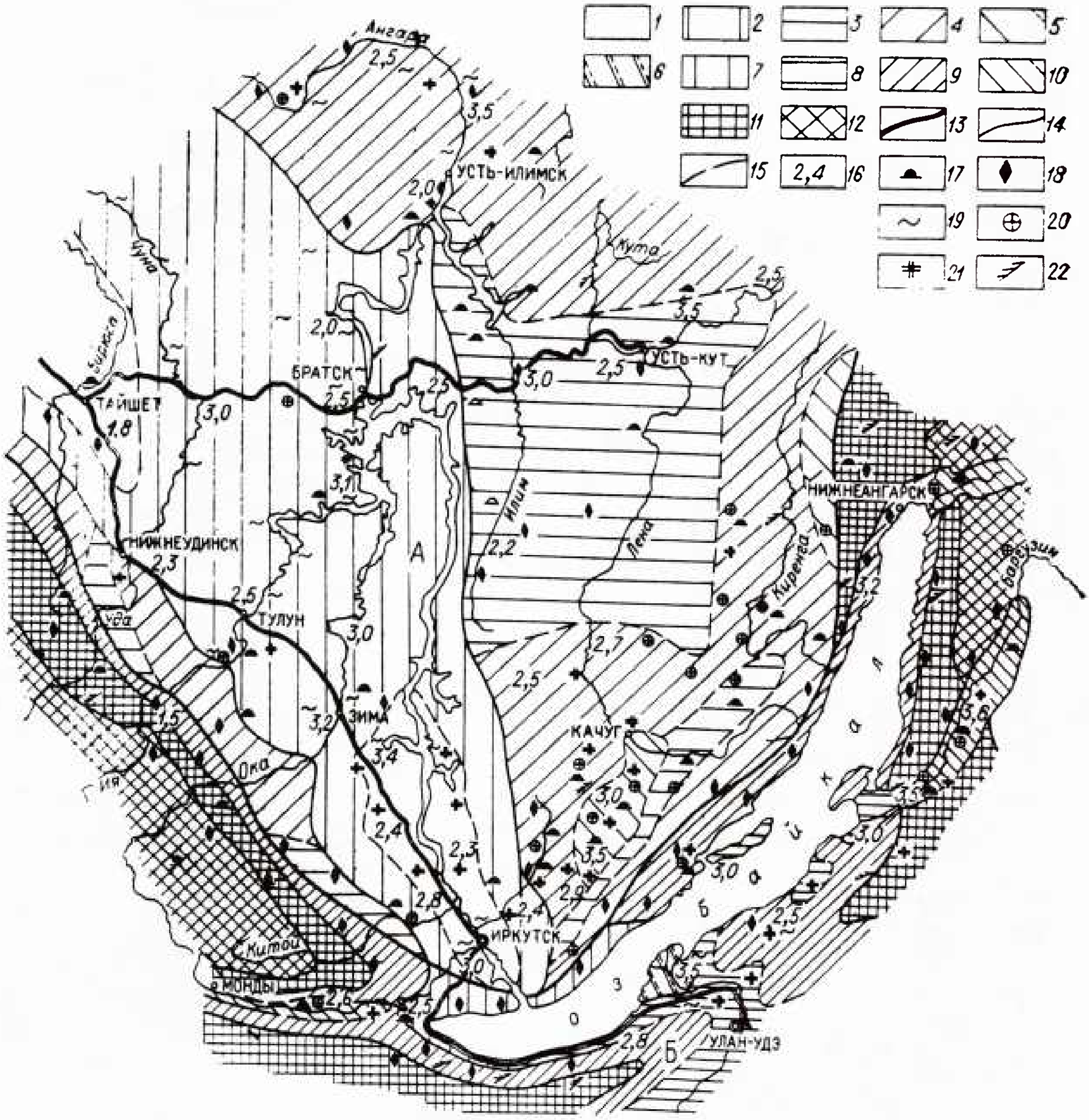


Figure A20. Permafrost division in the Angara River and Lake Baikal areas. (From Leshchikov 1978.)

Legend - Figure A20

A. Province of permafrost in the southern Siberian Platform

Area with rare permafrost islands with regions:

1 - without permafrost

2 - with rare islands and lenses of permafrost

Area of island distribution of permafrost with regions of:

3 - island permafrost in swampy areas and river valleys;

4 - island permafrost on all elements of relief;

5 - island permafrost in loose deposits of ancient valleys

B. Province of permafrost of Baikal fold-mountain zone

Area with rare permafrost islands with regions:

6 - without permafrost

7 - with rare permafrost islands

Area of island distribution of permafrost with regions of:

8 - island permafrost in river valleys;

9 - island permafrost on all elements of relief;

10 - island permafrost in inter-mountain areas;

Area of permafrost with talik islands with regions of:

11 - discontinuous permafrost;

12 - permafrost with rare taliks;

Permafrost boundaries:

13 - provinces;

14 - areas;

15 - regions;

16 - depth of seasonal ground freezing, m;

Permafrost phenomena:

17 - frost mounds;

18 - icing;

19 - hillocky sinkhole relief;

20 - thermokarst topography;

21 - polygonal microrelief;

22 - solifluction features;

Figure A21. Ice content of the upper horizons of permafrost in the west Siberian plain. (From Lur'e 1972.)

Legend - Figure A21

Genetic types and age of deposits:

1 - Recent alluvial deposits;

2,3 - Upper Quaternary alluvial deposits;

4,5 - Upper Quaternary lake-alluvial deposits;

6 - Recent marine deposits;

7,8,9 - Upper Quaternary marine-lagoon deposits;

10,11 - Upper Quaternary marine and shore-marine deposits;

Lithology and ice content (moisture content):

Permafrost:

12 - turf, high ice content;

13 - clayey silty loam, low ice content ($W_e<W_p$);

14 - clayey silty loam, average ice content ($W_p<W_e<W_T$);

15 - clayey silty loam, high ice content ($W_e>W_T$);

16 - sandy silty loam, low ice content ($W_e<W_p$);

17 - sandy silty loam, average ice content ($W_p<W_e<W_T$);

18 - sandy silty loam, high ice content ($W_e<W_T$);

19 - sands, low ice content ($W_e<W_\pi$);

20 - high ice content ($W_e<W_\pi$);

Unfrozen ground:

21 - sandy silty loam, low moisture content ($W_e<W_p$);

22 - sands, low moisture content ($W_e<W_\pi$);

Note: Deposits of turf have lake-swamp origin of the upper Quaternary and Contemporary period (lh QIII-IV) and appear in all lithological facies zones of the studied area as covering complexes.

Genetic types of monomineral ice:

23 - flat distribution of wedge ice;

24 - separate masses of wedge ice;

25 - ice cores of migration and injection origin in frost mounds and hydrolaccoliths;

26 - large collections of injected (segregated) ice in oriented ridges of relief;

Average annual ground temperature (°C):

27 - from 1° to 3°;

28 - from 0° to -1°;

29 - from -1° to -3°;

30 - from -3° to -5°;

31 - below -5°C

Boundaries:

32 - geological boundaries;

33 - permafrost distribution boundary;

34 - boundaries of frozen ground with various average annual temperatures;

35 - boundaries of frozen ground with various lithology and ice content.

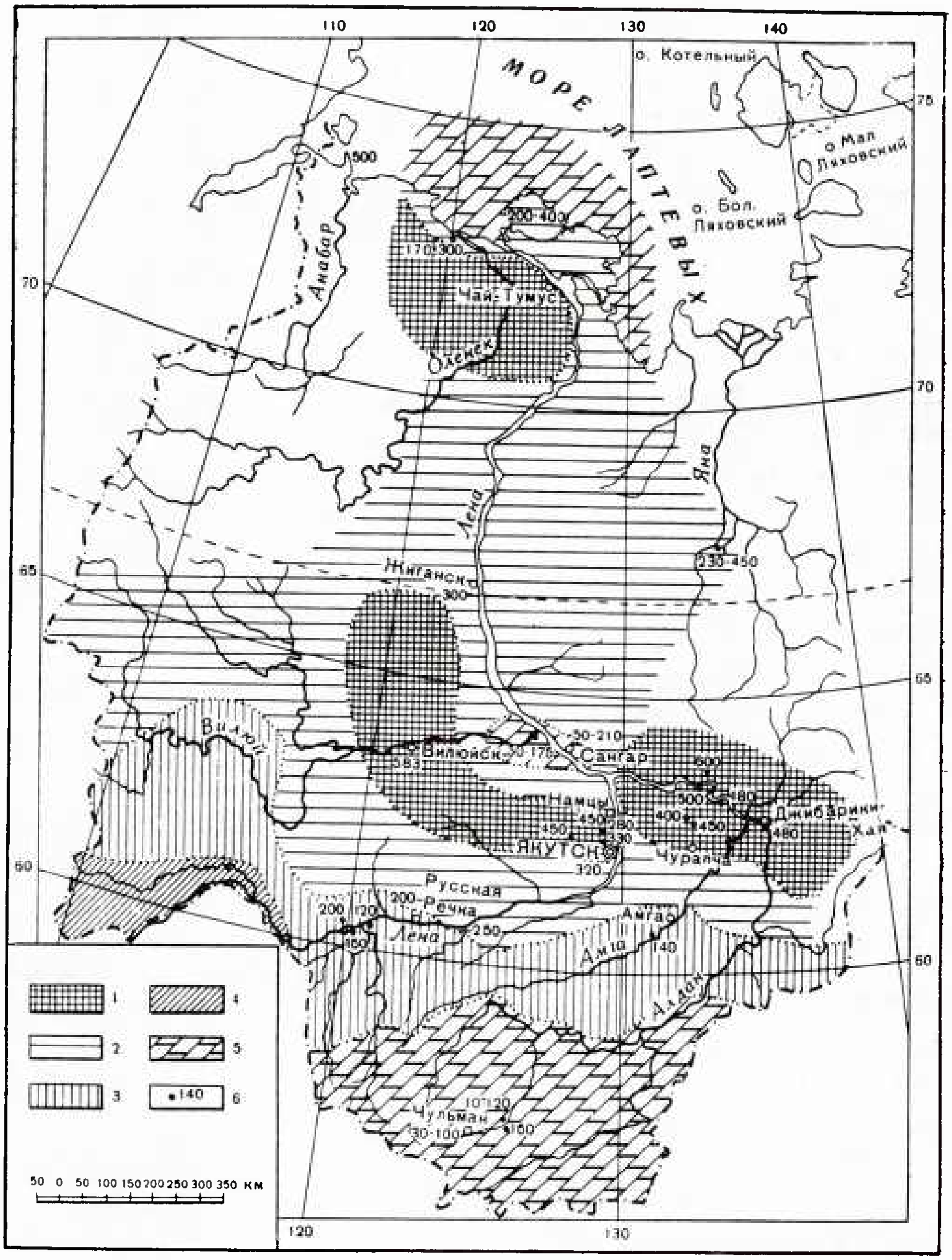


Figure A22a. Thickness of permafrost in Yakutsk ASSR. (From Mel'nikov 1959.)

Legend - Figure A22a

1 - permafrost thickness from 400 to 500 m and more;

2 - from 200 to 400 m;

3 - from 100 to 200 m;

4 - less than 100 m;

5 - from 100 to 200 m, and in some places less than 100 m;

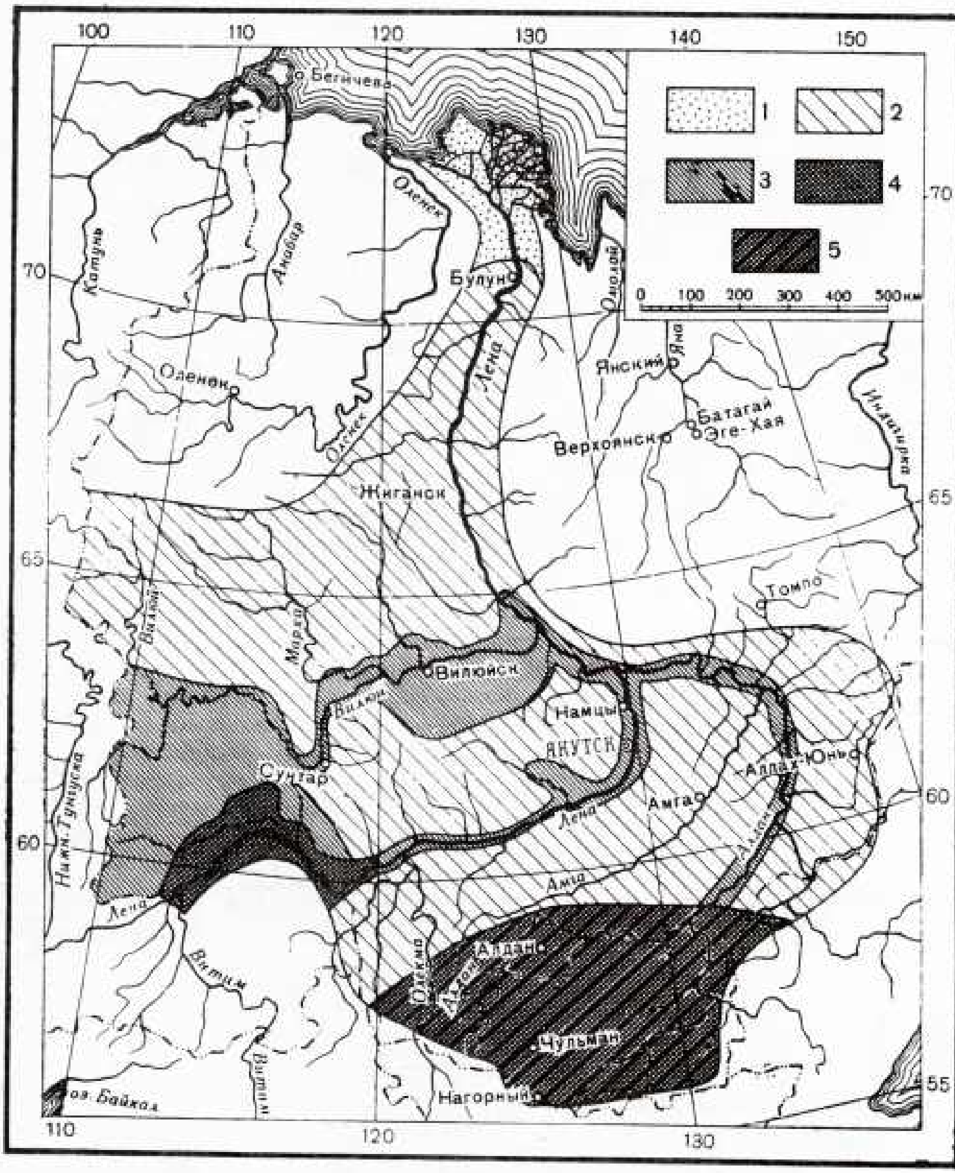


Figure A22b. Depth of seasonal thawing in Yakutsk ASSR. (From Mel'nikov 1959.)

Legend - Figure A22b

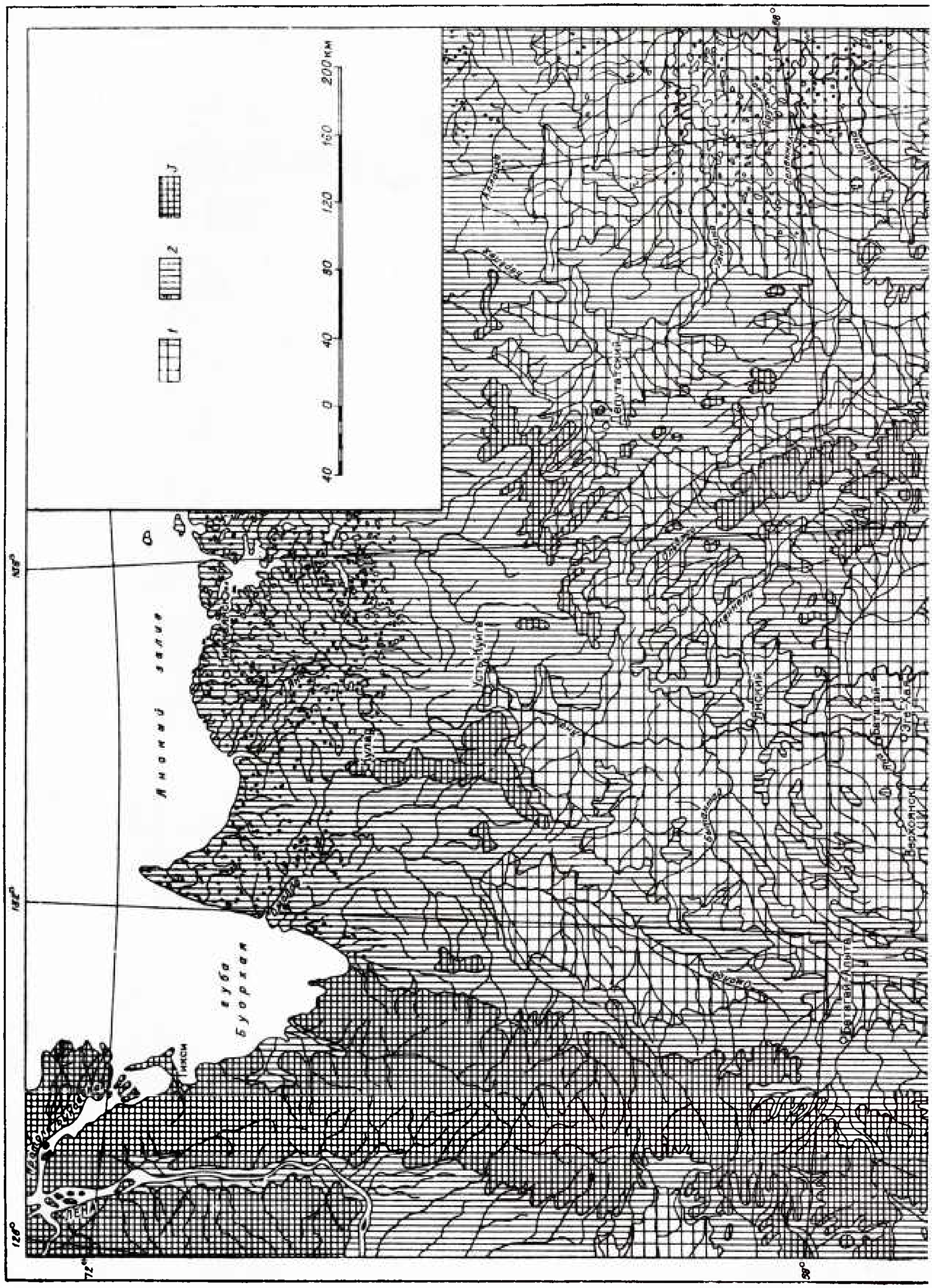
1 - the layer of seasonal thawing, less than 1 m;

2 - from 1 to 2 m;

3 - from 2 to 3 m;

4 - more than 3 m;

5 - from 2 to 3 m and more.


1
2
3
40 0 40 80 120 160 200 км
Янский залив
губа Буорхая
Лена
Верхоянск
Батагай

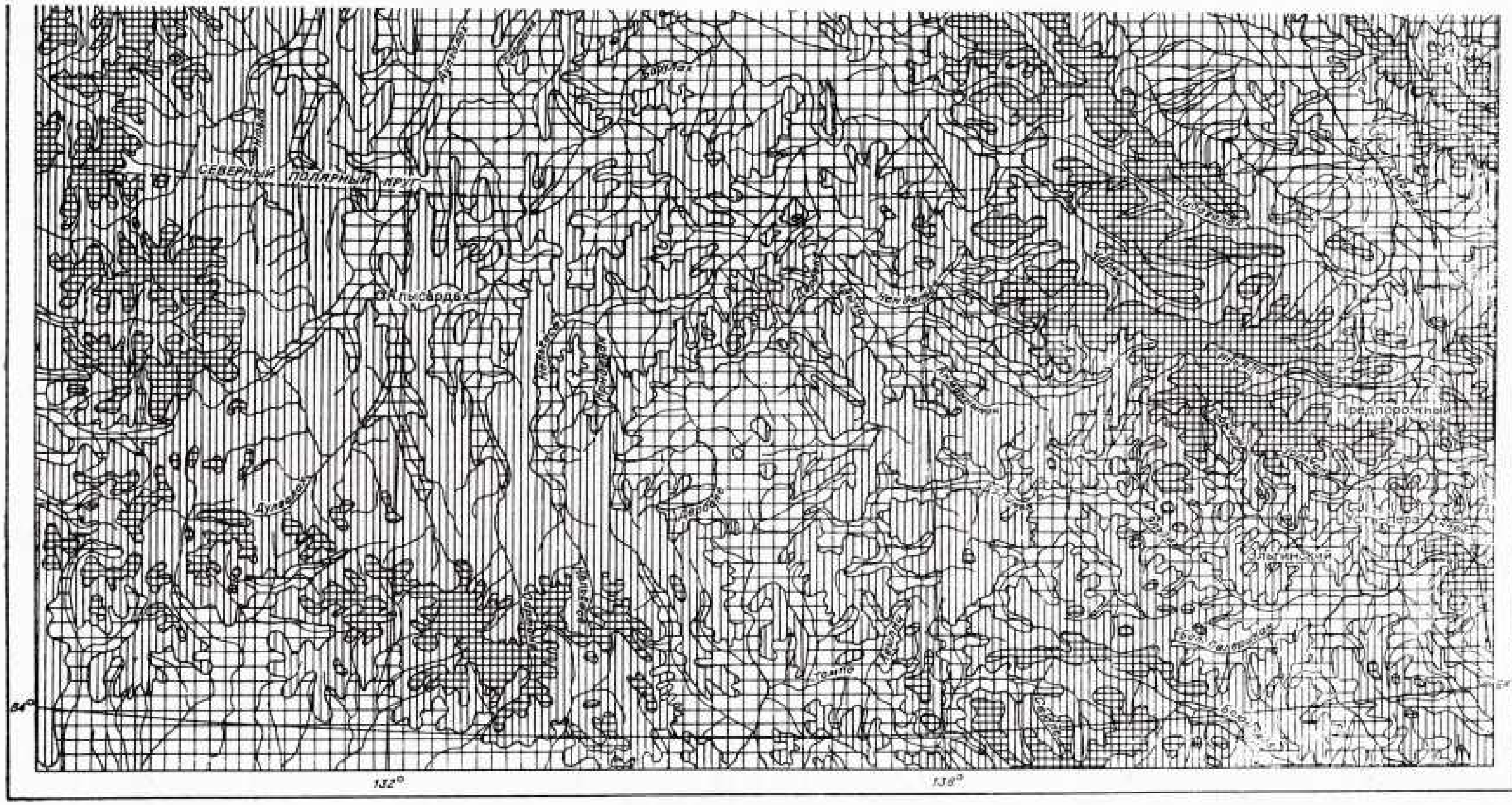


Figure A23a. Morphology and temperature of the permafrost zone of the Yana River and contiguous regions. (From Nekrasov and Deviatkin 1974.)

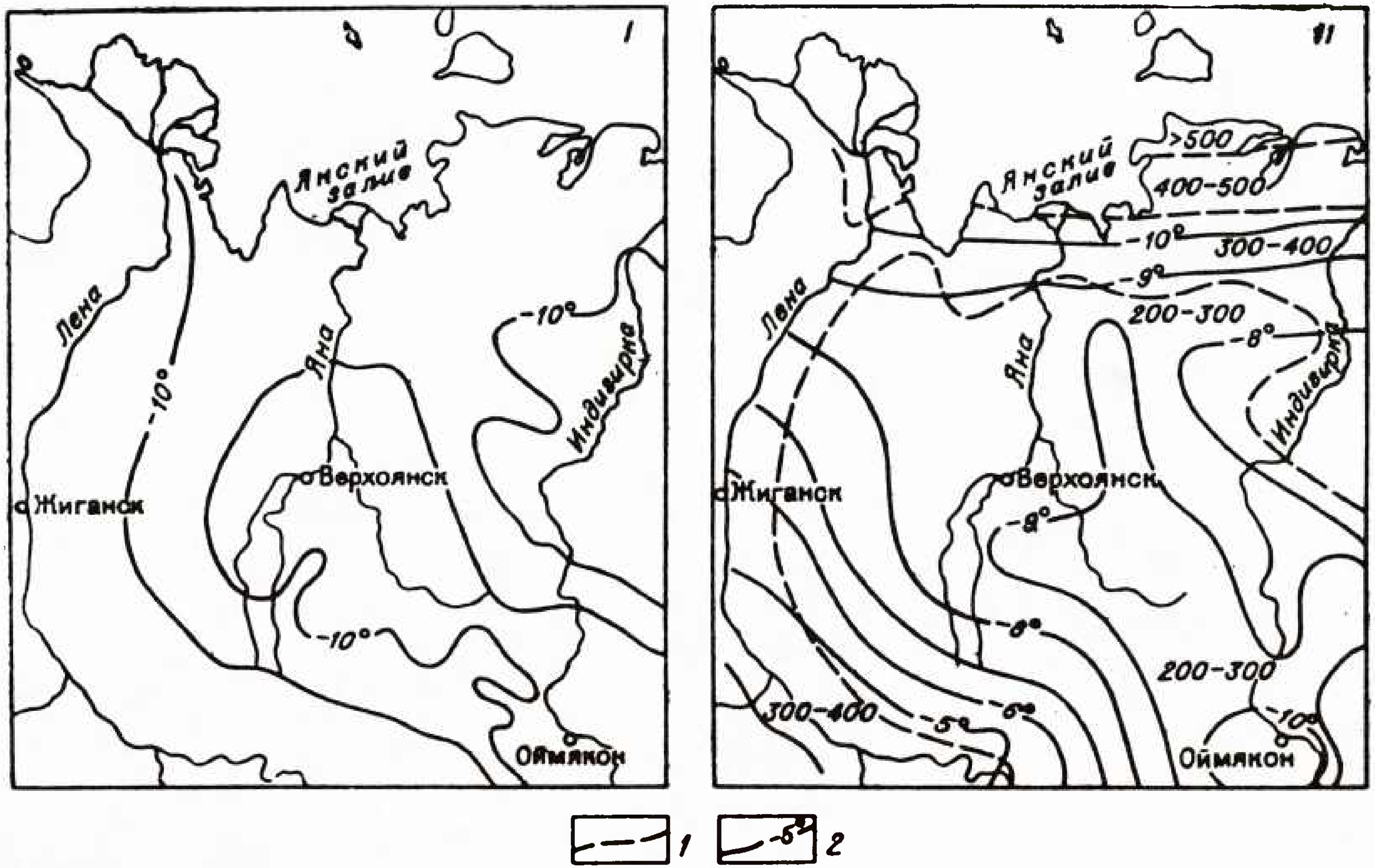
Legend - Figure A23a

Thickness of permafrost zone, temp (°C):

1 - 100-300 m, -1.0° to -9.0°;

2 - 300-500 m, -5.0° to -10.0°;

3 - >500 m, -8.0° to -12.0° and lower.



Legend - Figure A23b

I - P.F. Shvetsov (1951) and V.K. Yanovskomu;

II - I.Ya. Baranov (1960);

III - P.F. Shvetsov (1962);

IV - P.I. Mel'nikov (1968)

1 - isolines of equal permafrost zone thickness;

2 - geoisotherms, reflecting ground temperatures at the base of the layer of annual variations.

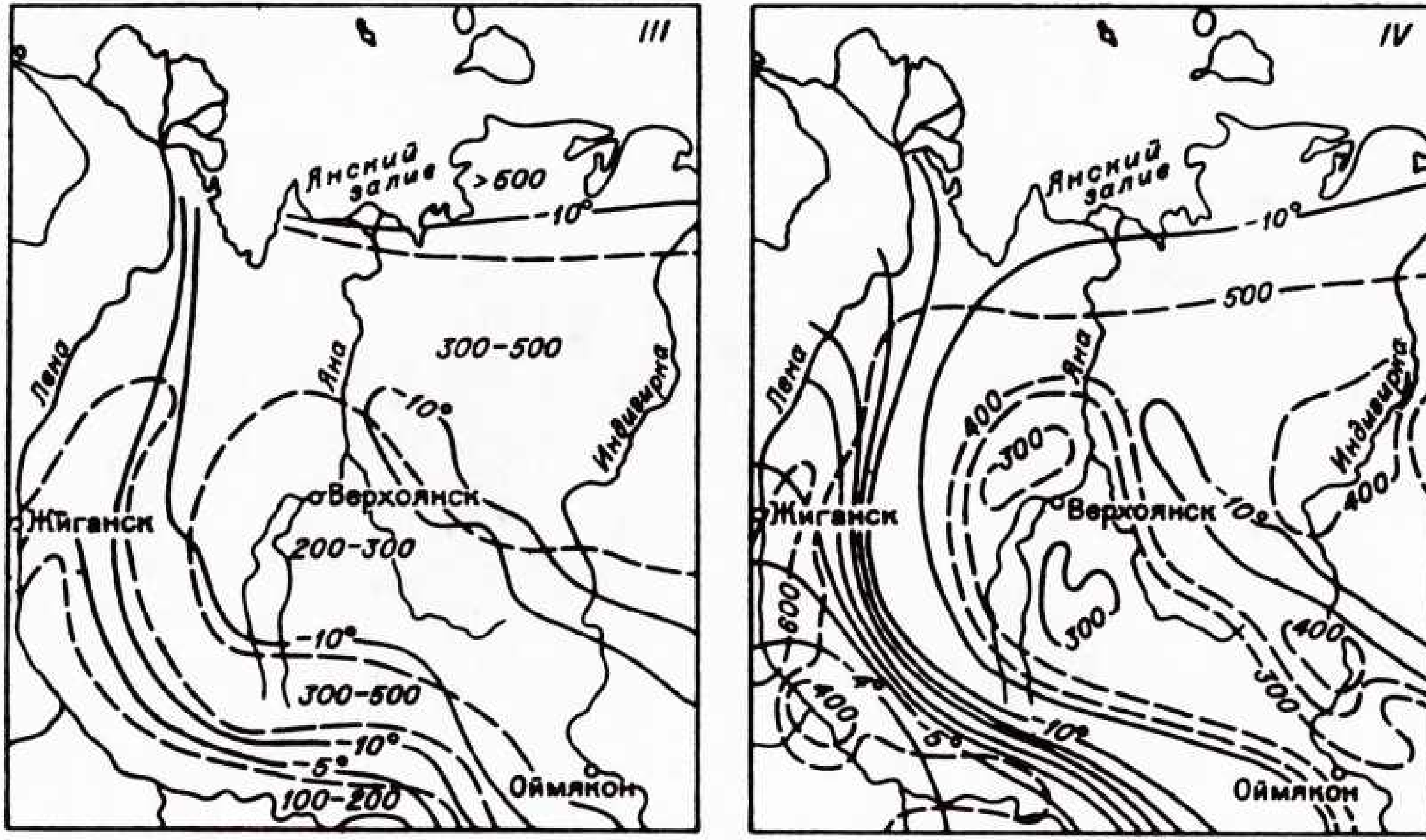


Figure A23b. Distribution of the morphology and temperature regimes of the permafrost zone of the Yana River basin and adjacent regions, according to various investigators. (From Nekrasov and Deviatkin 1974).

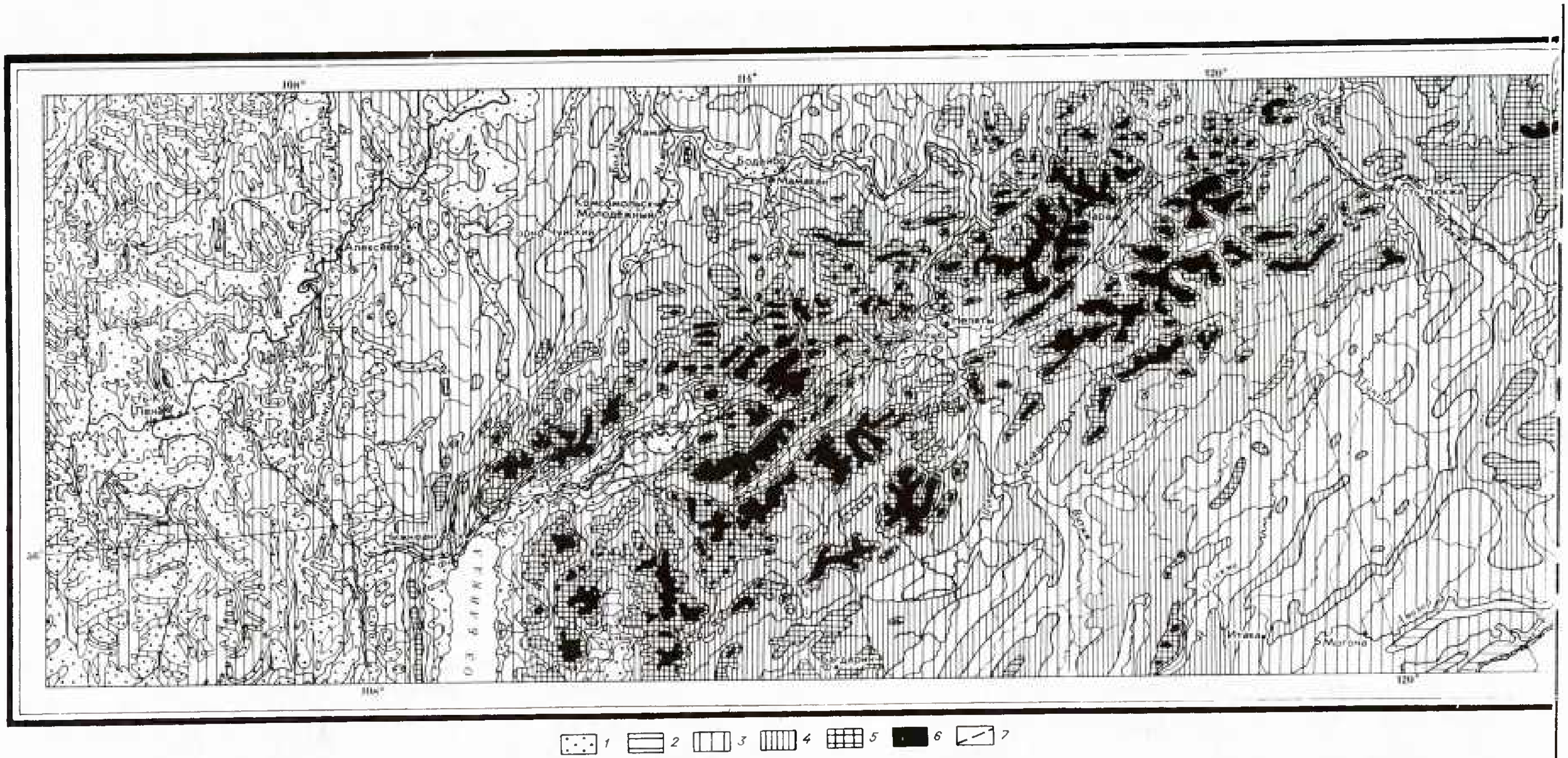
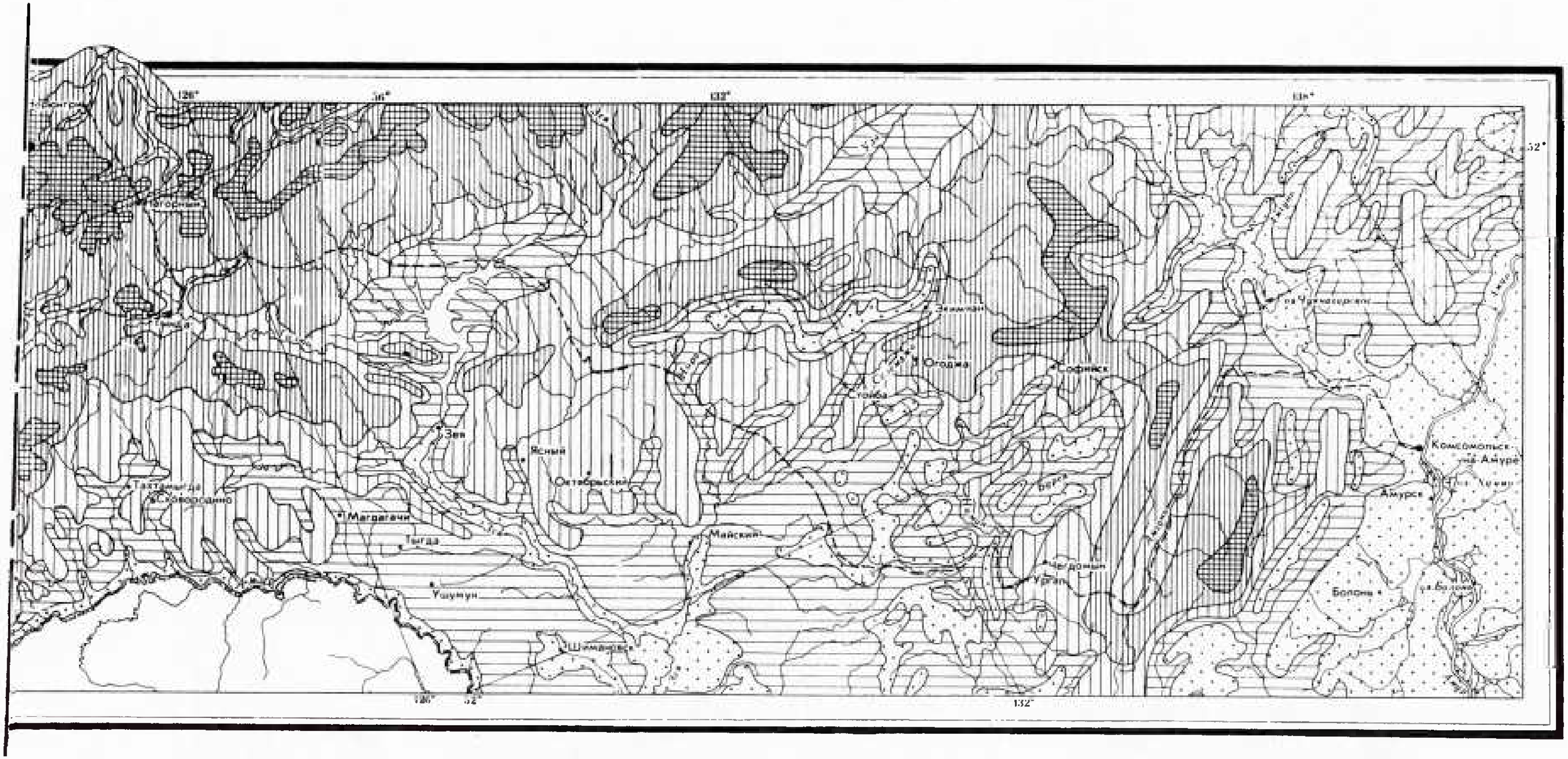


Figure A24a. Distribution of permafrost in the zone of the Baikal-Amur railroad. (From Nekrasov and Klimovskii 1978.)



Legend - Figure A24a

1 - region of deep seasonal freezing of ground, with possible short-term permafrost;

2 - regions of Far East with permafrost, thickness to 50 m, temp >1°C, frequent taliks on slopes with southern exposure and in areas with well-drained soils;

3 - same, thickness 50-100 m (in the Stanovovo highlands - thickness to 100 m), temp >-1.5°C, possible taliks on slopes with southern exposure;

4 - same, thickness 100-300 m, temp >-5°C;

5 - same, thickness 300-500 m, temp >-8°C;

6 - same, thickness >500 m, temp <-8°C;

7 - built and planned main line of the Baikal-Amur railroad.

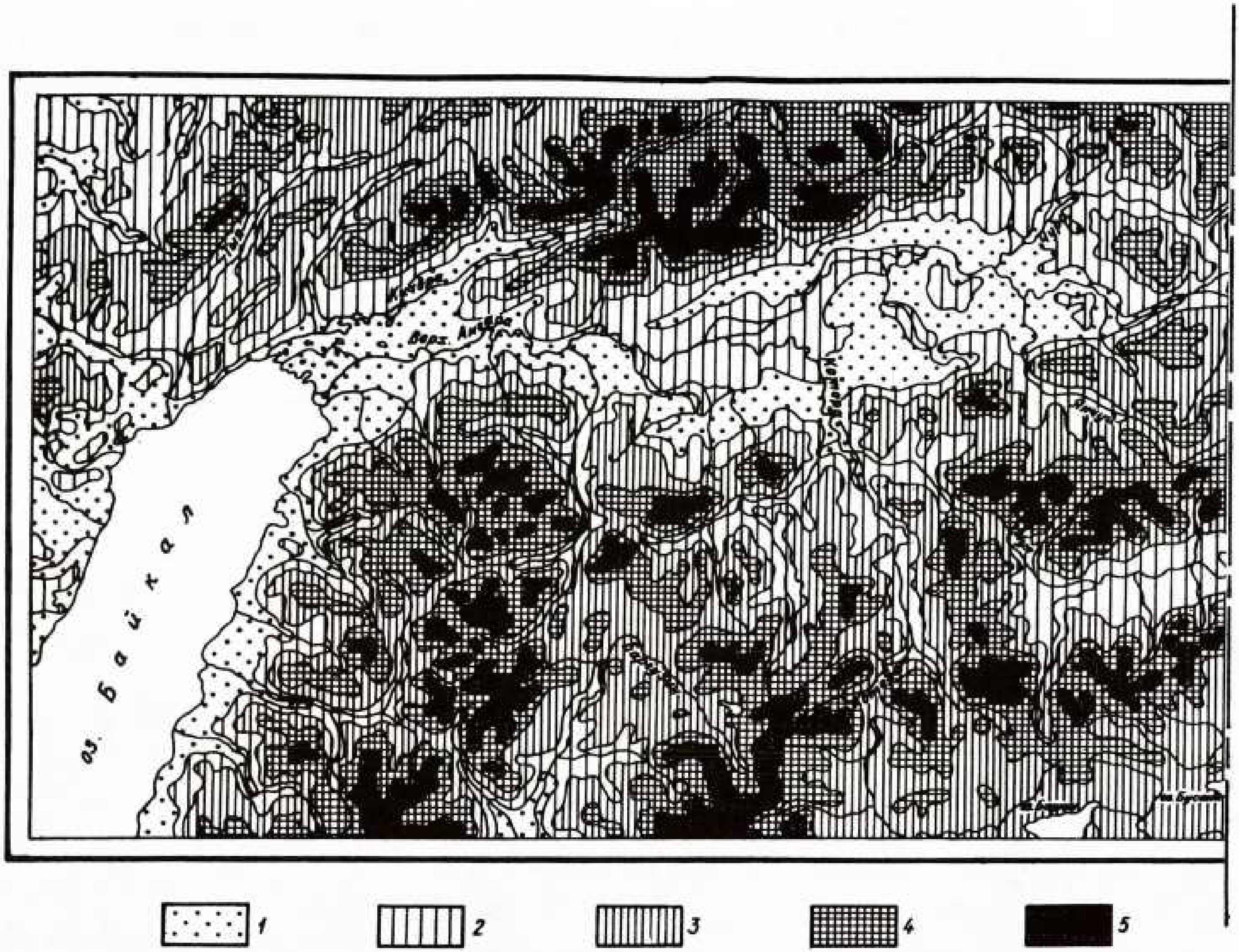
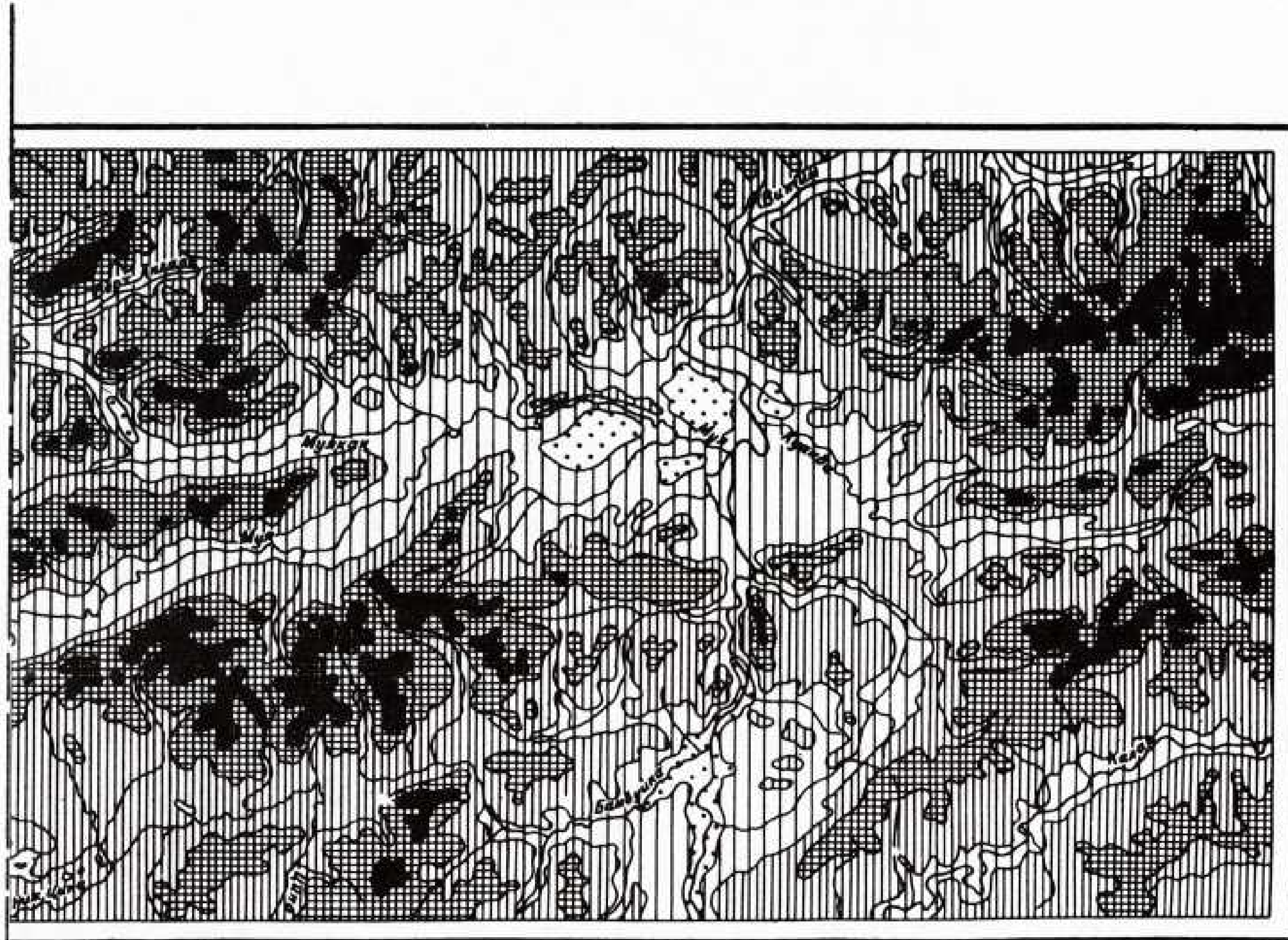


Figure A24b. Morphology and temperature of the permafrost in the Stanovovo highlands. (From Nekrasov and Klimovskii 1978.)



Legend - Figure A24b

1 - regions of talik with deep seasonal freezing of ground, with possible short-term permafrost;

2 - regions of permafrost with thickness to 100 m and temp to -1.5°C, possible taliks on the slopes with southern exposure;

3 - same, thickness 100-300 m, temp to -5°C;

4 - same, thickness 300-500 m, temp to -8°C;

5 - same, thickness >500 m, temp <-6°C.

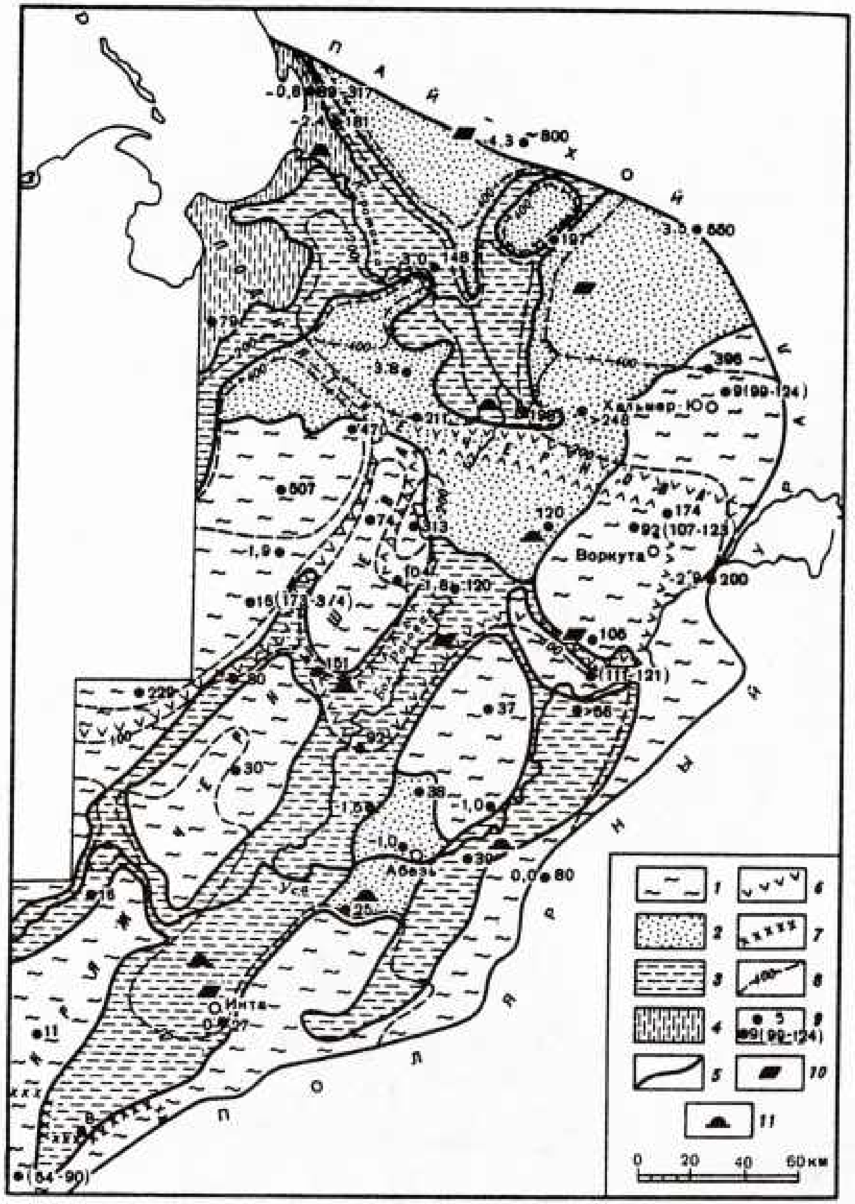


Figure A25. Permafrost of the Sub-Urals. (From Oberman 1981.)

Legend - Figure A25

Permafrost zones (areas of continuous subaerial development):

1 - thick and also two-layered and relic frozen masses (exist from the 1st phase of 2nd stage, Q_{II});

2 - thick and also two-layered and relic frozen masses with wide distribution of sheet ice (from 2nd phase, Q_{II-III});

3 - thin, colder in the south, frozen masses with sheet ice (from 3rd phase, Q^2_{III});

4 - thin frozen masses with sheet ice and subpermafrost kriopegs (from 4th phase, Q_{III}-Q_{IV});

Boundaries:

5 - zones;

6 - island distribution of permafrost (points of symbols toward permafrost);

7 - permafrost occurring at the surface;

8 - isolines of maximum thickness (in meters) of the permafrost, occurring at the surface (or of the top layer, in the case of two-layered structure);

9 - boreholes (numbers on the left- temperature of ground in °C; center-depth to bottom of permafrost in meters; on the right - depth to base of kriopegs; in parentheses- of relic permafrost);

10 - exposed sheet ice;

11 - perennial frost mounds with ice cores.

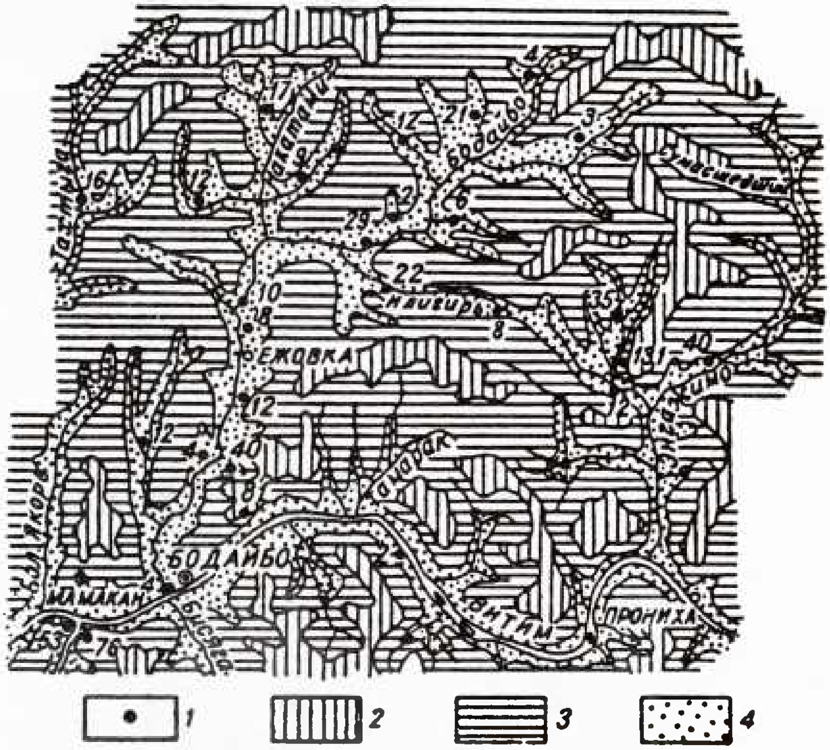


Figure A26. Permafrost of the southwestern part of the Lena gold region. (From Pinneker 1962.)

Legend - Figure A26

1 - some observation points with the thickness of the permafrost identified (the figures are the thickness in meters);

2 - area where the thickness of the permafrost is more than 100 meters;

3 - permafrost with taliks (the thickness of the permafrost is 50 to 100 meters);

4 - taliks with the maximum thickness of the islands of permafrost not more than 50 meters.

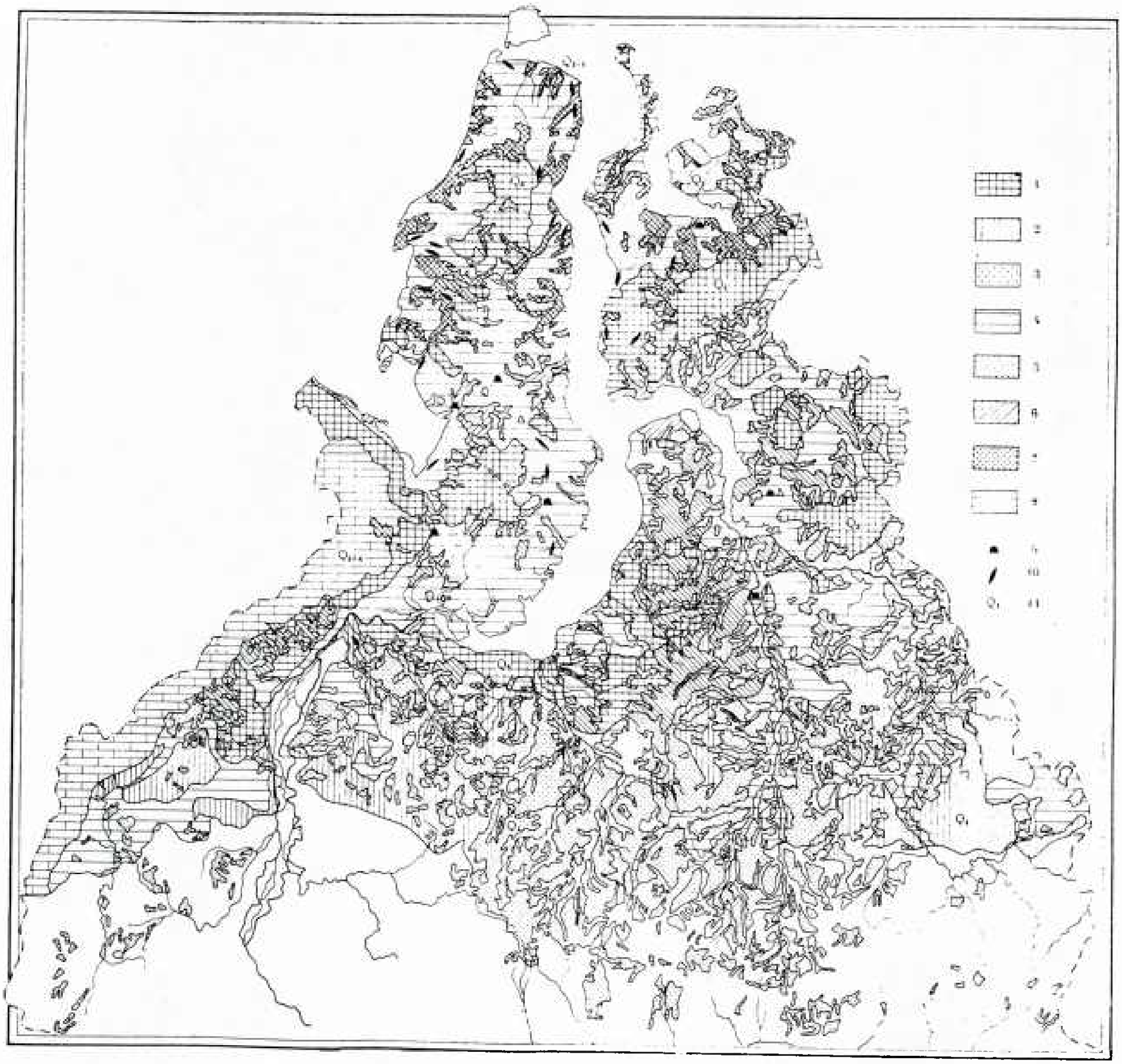


Figure A27. Cryogenic mountainous rock of western Siberia. (From Popov 1969.)

Legend - Figure A27

1 - frozen earth material, composed of clay, clayey silty loam, sandy silty loam (marine, ice-marine, lake, alluvial) with micro-reticulate and microlayered fine-schlieren cryogenic texture;

2 - frozen earth material, composed of clay, clayey silty loam, sandy silty loam (marine, ice-marine, lake, alluvial) with macro-reticulate and macrolayered thick-schlieren cryogenic texture;

3 - frozen earth material, composed of peat (swamp deposits) with massive cryogenic texture, underlain by clayey silty loam and sandy silty loam (lake-type) with reticulate and layered thick-schlieren texture (epigenetic freezing);

4 - frozen earth material, composed of sands and gravels (of various formations) with massive cryogenic texture (epigenetic, rarer syngenetic freezing);

5 - pure ground ice, composed of relic polygonal-wedge ice in combination with turf (from 0.5 to 5 m thickness) with massive cryogenic texture (epigenetic and syngenetic freezing);

6 - pure ground ice, composed of relic polygonal wedge ice in combination with peat, clayey silty loams and sandy silty loams with reticulate and layered fine-schlieren texture (syngenetic, rarer epigenetic freezing);

7 - pure ground ice, composed of developing polygonal-wedge ice in combination with peat, clayey silty loam and sandy silty loam with reticulate and layered fine-schlieren cryogenic texture (syngenetic, rarer epigenetic freezing);

8 - pure ground ice, composed of vein ice in tectonic and other fissures of crystalline and metamorphic mountain rock (epigenetic freezing);

9 - pure ground ice, composed of hydrolaccolith ice core (in alluvial, lake and swamp deposits);

10 - pure ground ice, composed of sheet ice bodies (frozen water-bearing horizons);

11 - age of ice formations.

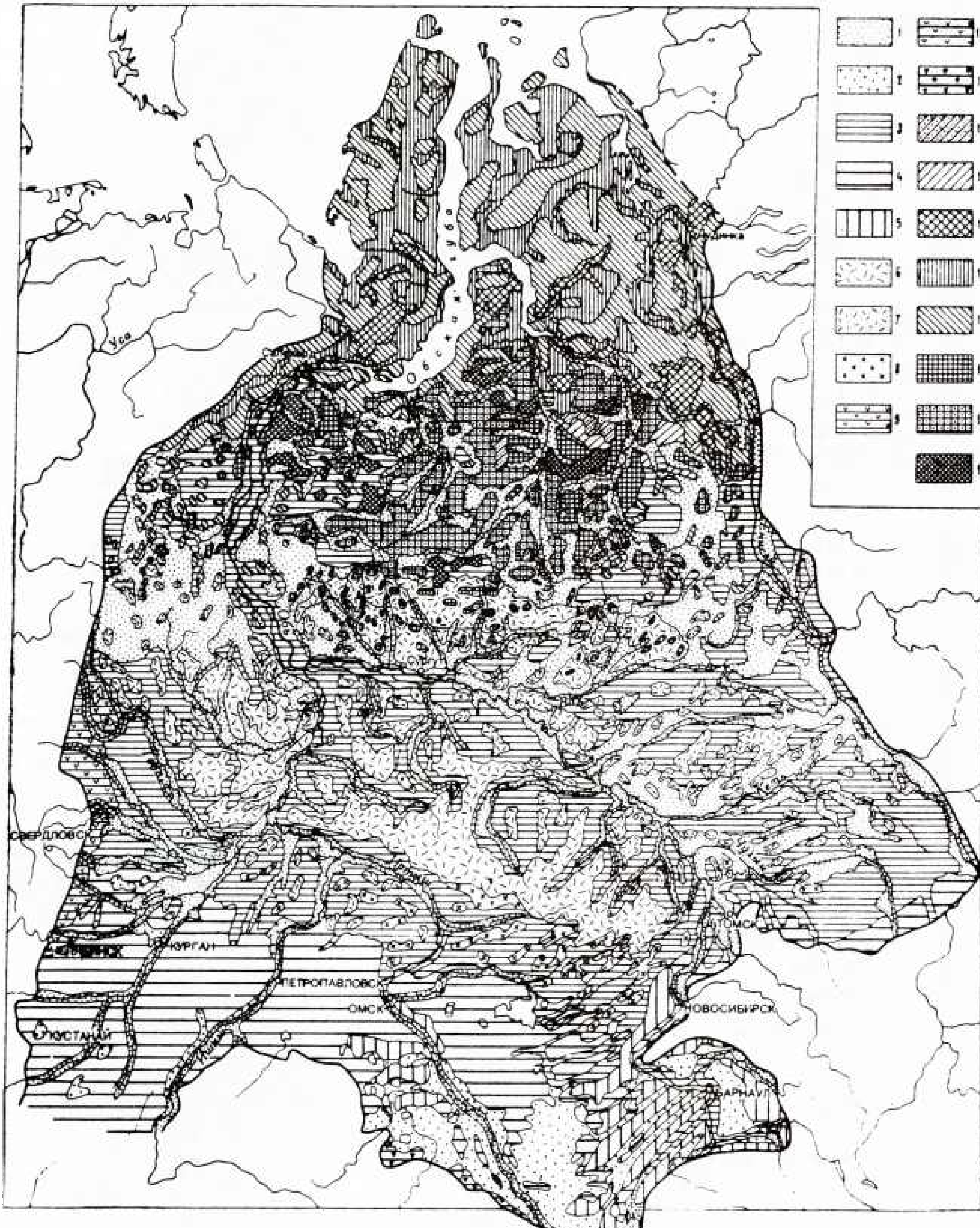


Figure A28. Surficial materials of the western Siberian platform (compiled by V.T. Trofimov and L.T. Datsko based on maps of ground rock masses, edited by E.M. Serreeva, 1972). (From Popov and Trofimov 1980.)

Legend - Figure A28

Surficial materials - unfrozen and talik:

1 - Primarily sandy, high moisture content;

2 - Primarily sandy, moderate moisture content;

3 - Primarily clayey, high moisture content;

4 - Primarily clayey and loess unsettled, moderate moisture content;

5 - Loess, moderate moisture content, settled;

6 - Peat, high moisture content;

7 - Peat and sandy (peat - thickness to 2 m, underlain by sand) high moisture content;

8 - Peat-clayey, high moisture content

9 - Clayey-flinty (clay types thickness up to 5-9 m, underlain by diatomites and opoka), high moisture content;

10 - Clayey-flinty, moderate moisture content;

11 - Clayey-rock debris, moderate moisture content;
Surficial materials - permafrost in the lower parts of the cross section and unfrozen in the upper;

12 - Primarily sandy, high moisture content, underlain by permafrost below 5-9 m;

13 - Primarily clayey, high moisture content, underlain by permafrost below 4-9 m;

Permafrost in surficial materials

14 - Primarily sandy, moderate ice content;

15 - Primarily sandy, high ice content;

16 - Primarily clayey, moderate and high ice content;

17 - Peat, high ice content;

18 - Peat-sandy, high ice content;

19 - Peat-clayey, high ice content

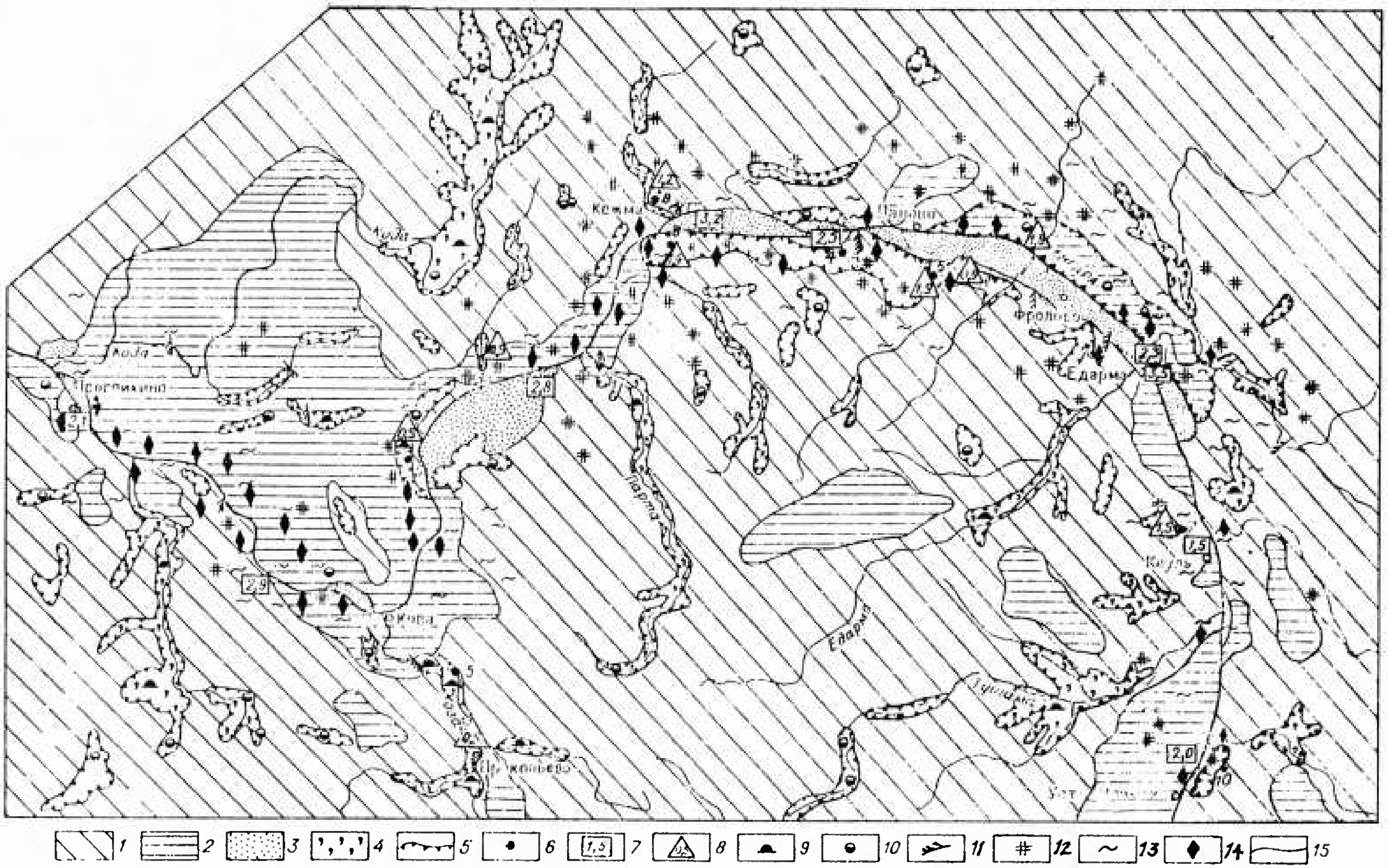


Figure A29. Permafrost conditions of the territory of the Boguchansk Reservoir. (From Serov and Leshchikov 1978.)

Legend - Figure A29

1 - silty alluvial-talus and alluvial clayey silt loam and sandy silty loam on interfluves, slopes and terraces;

2 - gravelly alluvial-talus clayey silty loam and sandy silty loam on basalts, sandstones, limestones and to some extent tuffs;

3 - alluvial-talus sands on sandstones, aleurolites of the Katsk suite and alluvial sands on high, intermediate and low terraces;

4 - muddy soils and peat soils;

5 - areas with permafrost;

6 - established thickness of permafrost (m);

7 - depth of seasonal freezing of soils (m);

8 - depth of seasonal thawing of soils (m);

9 - heaving mounds;

10 - thermokarst sinkholes and lakes;

11 - soil solifluction;

12 - fissure-polygonal micro-relief;

13 - mound-sinkhole micro-relief;

14 - ice crust;

15 - boundary of rock distribution.

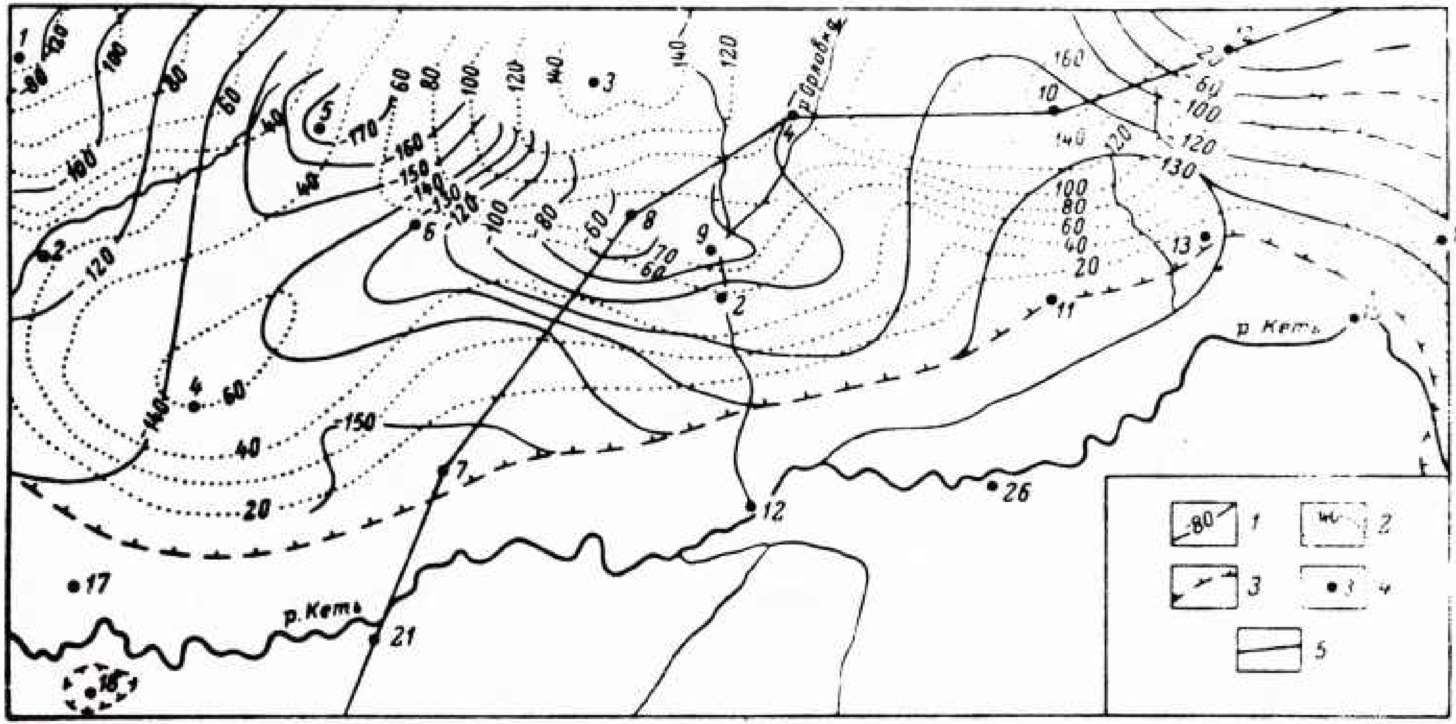


Figure A30. Distribution of deep-seated permafrost in the south of the western Siberian platform. (From Shamakhov and Zemtsov 1979.)

Legend - Figure A30

1 - contour lines of the depth to the top of permafrost, in absolute terms (m)

2 - isopach lines connecting points of equal permafrost thickness (m)

3 - southern boundary of permafrost;

4 - borehole and number;

5 - section line.

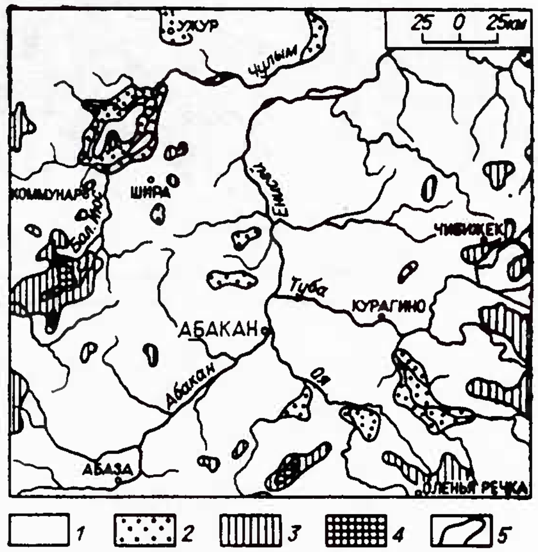


Figure A31. Distribution of mountainous permafrost in the southern part of the Krasnoyarsk region. (From Shats 1980.)

Legend - Figure A31

1 - seasonal freezing;

2 - sporadic permafrost;

3 - island permafrost;

4 - discontinuous permafrost;

5 - boundaries between various types of permafrost.

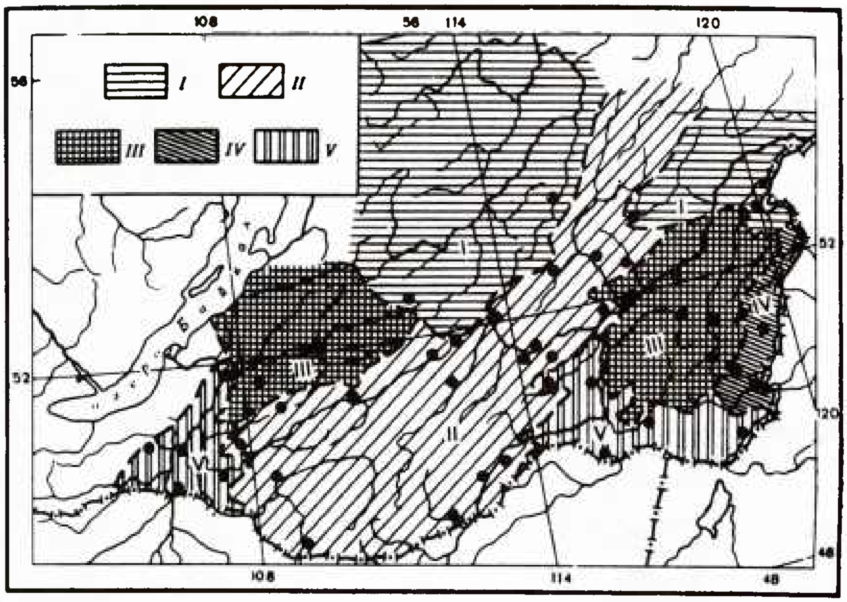


Figure A32. Division of the Zabaikal permafrost (legend - see Table A32). (From Shpolianskaia 1978.)

Table A32. Basic characteristics of the Zabaikal permafrost

Region	Character of permafrost distribution	Ground temp (°C)			Permafrost thickness (m)		
		Valley	Northern slope	Southern slope	Valley	Northern slope	Southern slope
I	Continuous	<-3	--	-1.2	150	--	80-90
II	Discontinuous, with individual islands of talik	-2 to -3	-1.5	+1.2	100	70	Talik
III	Discontinuous, with significant sections of talik	-0.5 to -1.0	-0.2 to -0.5	+3.5	30-40	10-15	Talik
IV	Islands, with significant sections of permafrost	-0.5	-0.5	>0.3	10-20	10-20	Talik
V	Island, with individual islands of permafrost	-0.2 to -0.3	-0.2 to +0.5	2 to 15	10 to Talik		Talik

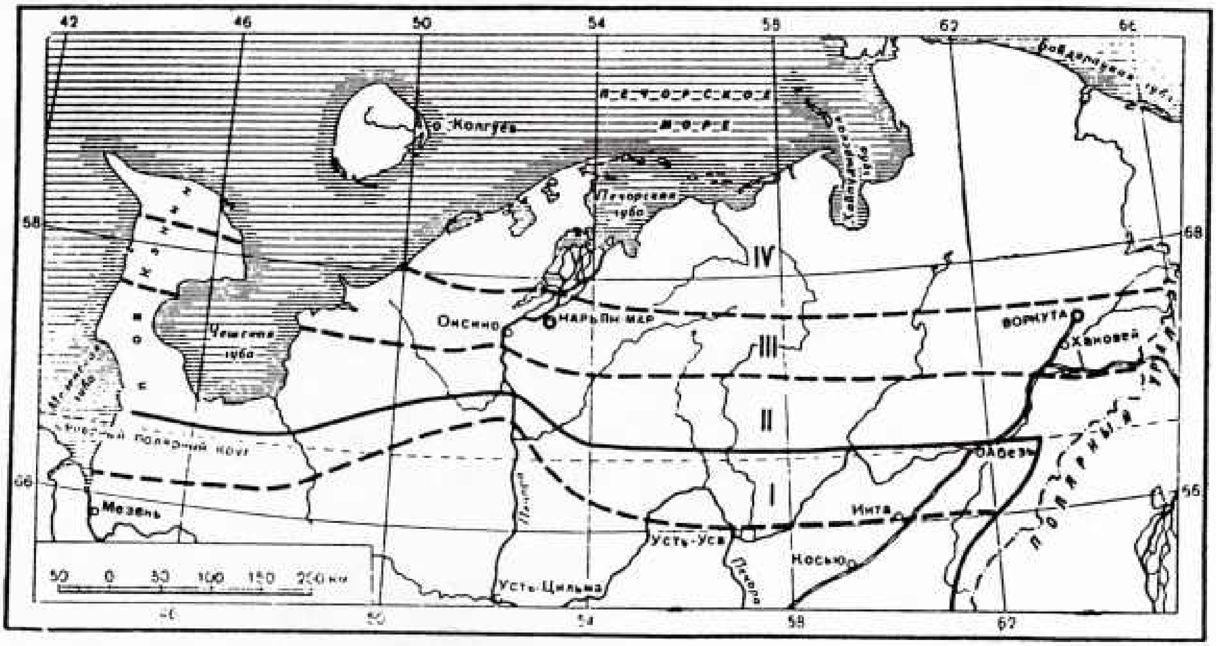


Figure A33. Geocryology of the northern European part of the USSR (compiled by T.F. Ivanovna). (From Shvetsov 1963.)

Legend – Figure A33

I – territory with permafrost lenses in peat mounds, thickness of lenses 10 to 20 m, temperature at a depth of 10 to 12 m close to 0°C;

II – territory with islands of permafrost on areas of flat peat and mottled tundra, thickness of frozen deposits 25 to 30 m, temperature at a depth of 10 to 12 m, -1°C;

III – territory with more permafrost than talik. Thickness of permafrost 100 m, temperature at a depth of 10 to 12 m varies from -1.5° to -2°C;

IV – territory of almost continuous permafrost distribution, with problems associated with beds of large rivers and lakes. Thickness of permafrost 150 to 200 m, temperature from -2° to -3°C;

——— southern boundary of distribution of mountainous permafrost;

- - - boundaries between belts.

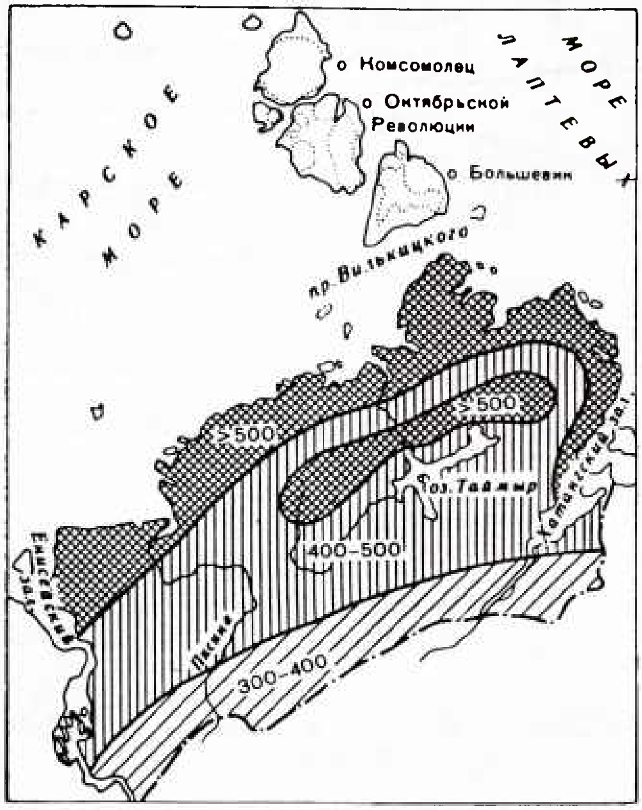


Figure A34a. Boundaries of probable maximum permafrost thickness (m) on the Taymyr Peninsula, after Baranov. (From Sisko 1970.)

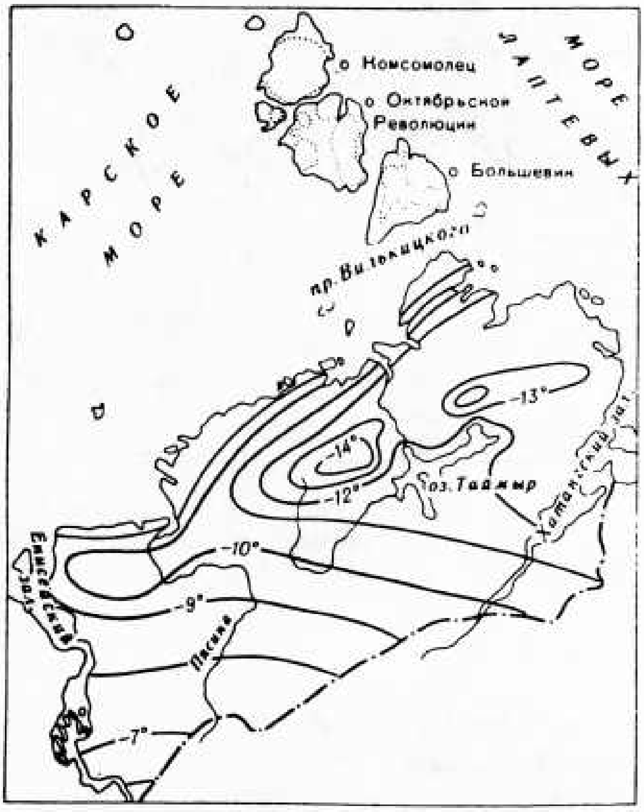


Figure A34b. Isotherms at the base of the layer with yearly temperature variations (°C), after Baranov. (From Sisko 1970.)

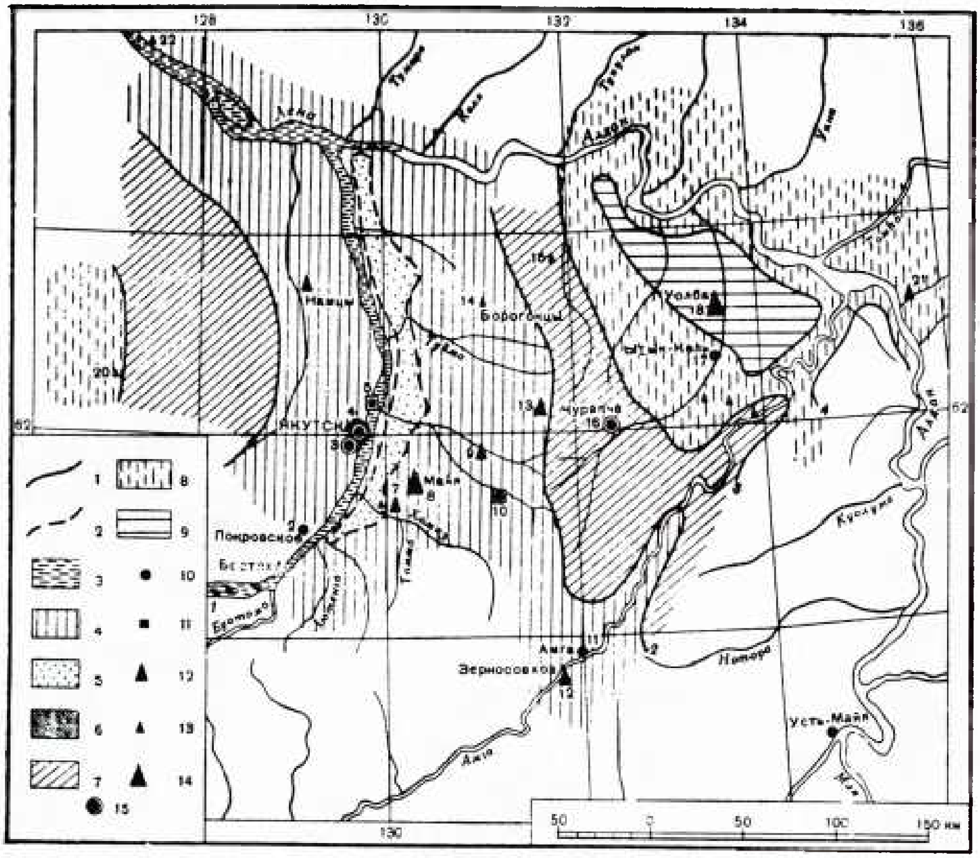


Figure A35. Division into districts of the Lena-Amga interfluve by maximum yearly ground temperature at depths of 3-10 m. (From Solov'ev 1959.)

Legend - Figure A35

1 - boundaries of temperature zones;

2 - boundaries of subzones;

3 - first zone;

4 - second zone;

5 - subzone 2a;

6 - subzone 2b; (characteristics of zones in Table A35)

7 - third zone;

8 - fourth zone;

9 - fifth zone;

10 - points of geothermal observations with yearly cycles;

11 - points of geothermal observations with partial yearly cycles;

12 - points of one-time geothermal observations;

The size of the markings indicate the relative number of boreholes in the area:

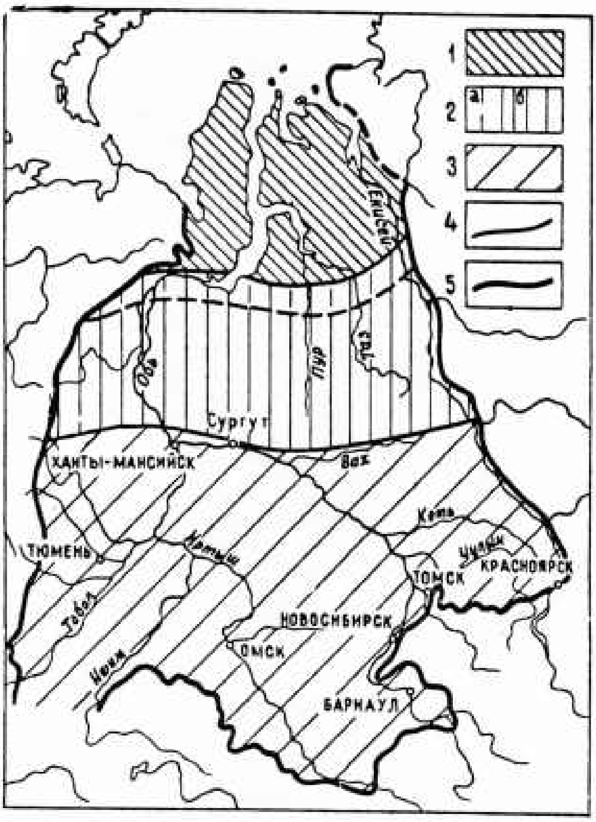
13 - individual boreholes;

14 - 2-3 boreholes;

15 - more than 5 boreholes.

Table A35. Ground temperatures in the Lena-Amga interfluve.

Zone	Typical region	Maximum (°C) (by depth in m)			Minimum (°C) (by depth in m)			Average annual temperature (°C)	
		3	5	10	3	5	10	from	to
	Area with meadow growth, clayey silty loam of neutral exposure, far from reservoirs or abrupt relief, not flooded by talik water.								
1	Lena flood plain	-	0.0	+0.5	-10.0	-2.0	-1.0	-	-
2	Abalakh	0.0	-0.8	-1.5	-12.0	-8.0	-4.5	-2.0	-3.5
3	Churapcha	-1.0	-2.0	-3.5	-14.0	-9.0	-6.5	-3.5	-5.0
4	Ytyk-Kel	-2.0	-3.0	-4.0	-14.0	-10.0	-8.5	-4.0	-6.0
5	Uolba	-2.5	-3.5	-4.5	-15.0	-11.0	-9.0	-5.0	-7.0
2a	Subzone Bestyakh	+1.0	-0.0	-1.0	-12.0	-7.0	-4.5	-	-
2b	Subzone Yakutsk	-3.5	-4.5	-6.0	-15.0	-12.0	-8.0	-5.0	-8.1
	Area with forest growth of medium and greater denseness, with the same conditions as above.								
1	Lena flood plain				No data				
2	Abalakh	-0.5	-1.5	-2.5	-12.0	-8.0	-5.0	-	-
3	Churapcha	-2.0	-3.0	-4.0	-14.0	-9.0	-6.0	-	-
4	Ytyk-Kel	-2.5	-4.0	-5.0	-	-	-	-	-
5	Uolba	-3.0	-4.5	-5.0	-	-	-	-	-
2a	Subzone Bestyakh				No data				
2b	Subzone Yakutsk	-	-	-	-	-	-	-	-



Legend - Figure A36a

1 - zone of practically continuous distribution of permafrost;

2 - discontinuous (by area) distribution of permafrost, a) subzone of development of permafrost with islands of talik (seasonal-freezing) rock; b) subzone of simultaneous widespread development of permafrost and seasonally freezing rock;

3 - zone of distribution of seasonally freezing rock;

4 - boundaries of freezing zone;

5 - boundary of Western Siberian Platform

Figure A36a. Permafrost zones of the western Siberian platform. (From Trofimov et al. 1980.)

Table A36. System of the larger territorial cryolithological units of the Western Siberian Platform.

Province	Zone	Subzone
Development of permafrost within the limits of the continental part of the region Continental (K)	Practically continuous permafrost distribution (KA)	Simultaneus wide development of syncryogenic and epicryogenic types (K A_1)
		Development of primarily epicryogenic types (KA_2)
	Discontinuous permafrost distribution (K5)	Development of epicryogenic types (Kb_1)
Development of permafrost and criopegs within the limits of the water area of the Kara Sea and Gulf shelf (W)	Discontinuous (?) distribution of permafrost and criopegs (WA)	Development of syncryogenic and epicryogenic types (WA_1)

Note: Letters in parentheses correspond to the index of the given territorial units in Figure A36b.

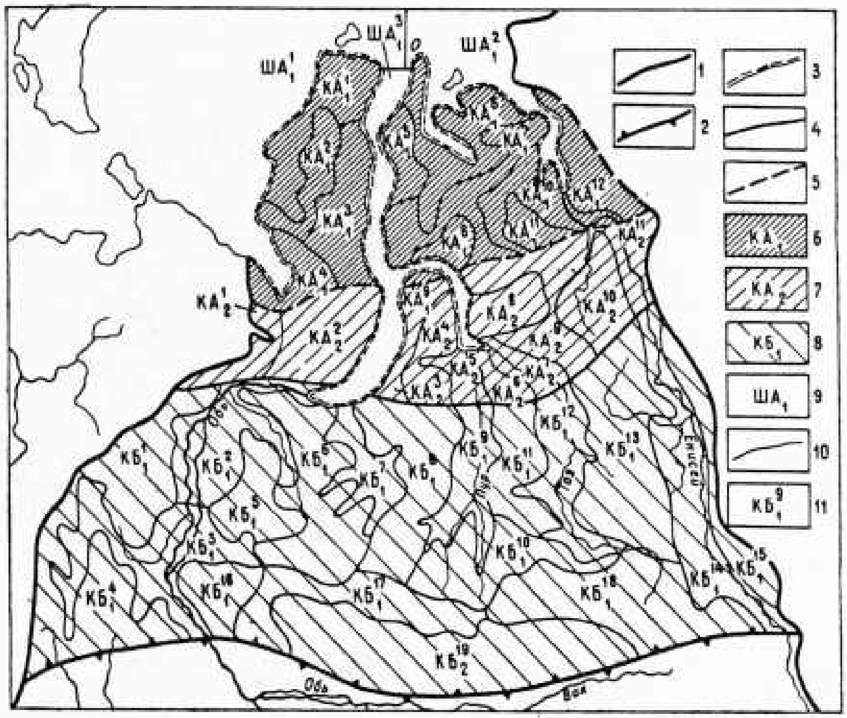


Figure A36b. Cryolithological division of permafrost development in territories of the western Siberian platform. (From Trofimov et al. 1980a.)

Legend - Figure A36b

1 - boundary of Western Siberian Platform;

2 - southern boundary of distribution of permafrost in the upper part of the platform cross section;

3 - boundary of cryolithological provinces (see Table A36);

4 - boundary of cryolithological zone (see Table A36);

5 - boundary of cryolithological subzone;

6 - subzone of simultaneous widespread development of syncryogenic epicryogenic permafrost of the Continental province;

7 - subzones of primarily development of epicryogenic permafrost of the same province;

8 - subzone of development of epicryogenic permafrost of the same province;

9 - subzone of development of syncryogenic and epicryogenic permafrost of the shelf province;

10 - boundary of cryolithologic regions;

11 - index of cryolithologic regions.

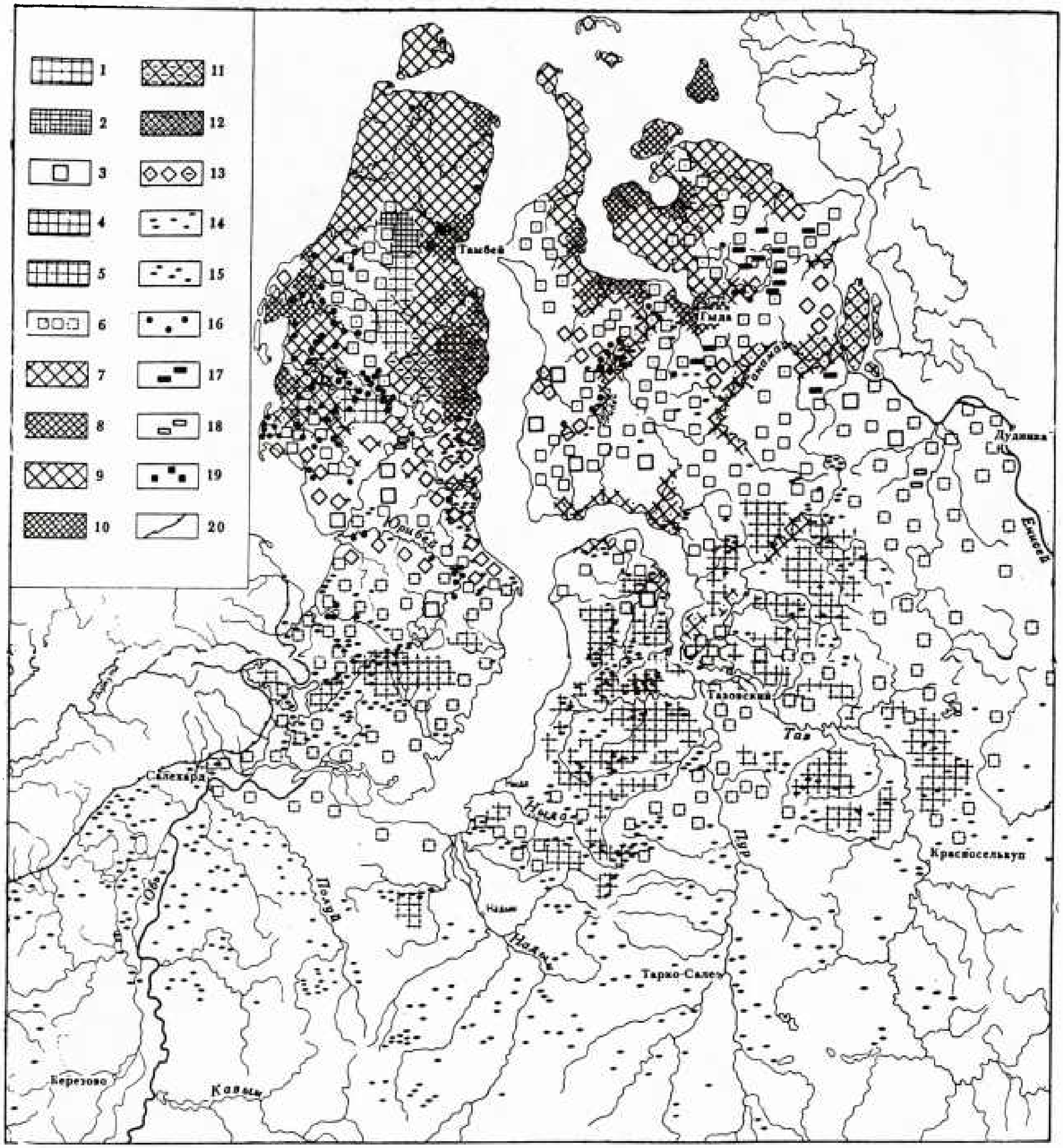


Figure A36c. Genetic types of ground ice and macro-ice content of the top 10-m section of deposits on the western Siberian platform. (From Trofimov et al. 1980a.)

Legend - Figure A36c

1 - epigenetic polygonal wedge ice in growth stage in mineral grounds, volume of macro-ice content, Iv < 5%

2 - the same, Iv = 5-20%

3 - epigenetic polygonal wedge ice in conservation and thawing stage, Iv < 5%;

4 - the same, Iv = 5-20%;

5 - epigenetic polygonal wedge ice in organic ground, Iv = 5-10%;

6 - separate plots of discontinuous distribution of above-listed ice types, not representable on the scale of this map;

7 - syngenetic polygonal wedge ice growth stage, Iv = 5-20%;

8 - the same, Iv > 20%;

9 - relict syngenetic polygonal wedge ice in conservation stage, Iv = 5-20%;

10 - the same, Iv > 20%;

11 - relic syngenetic polygonal wedge ice with an upper epigenetic stage, Iv = 5-20%;

12 - the same, Iv > 20%;

13 - separate plots of discontinuous distribution of above listed ice types, not representable on the scale of this map, Iv = 5-20%.

14 - Injected ice (ice cores of hydrolaccoliths, ice and ice-ground cores of frost mounds);

15 - injected ice in lake deposits of the upper Quaternary and Holocene age;

16 - sheet injected-segregated ice and injected ice in dislocated mid and upper Quaternary rock;

17 - large deposits of settled ice (at depths 5-25 m);

18 - the same, at depths >100 m;

19 - buried lake, river and other ice of unclear genesis;

20 - boundary of outcrops of Paleozoic rock of the Urals;

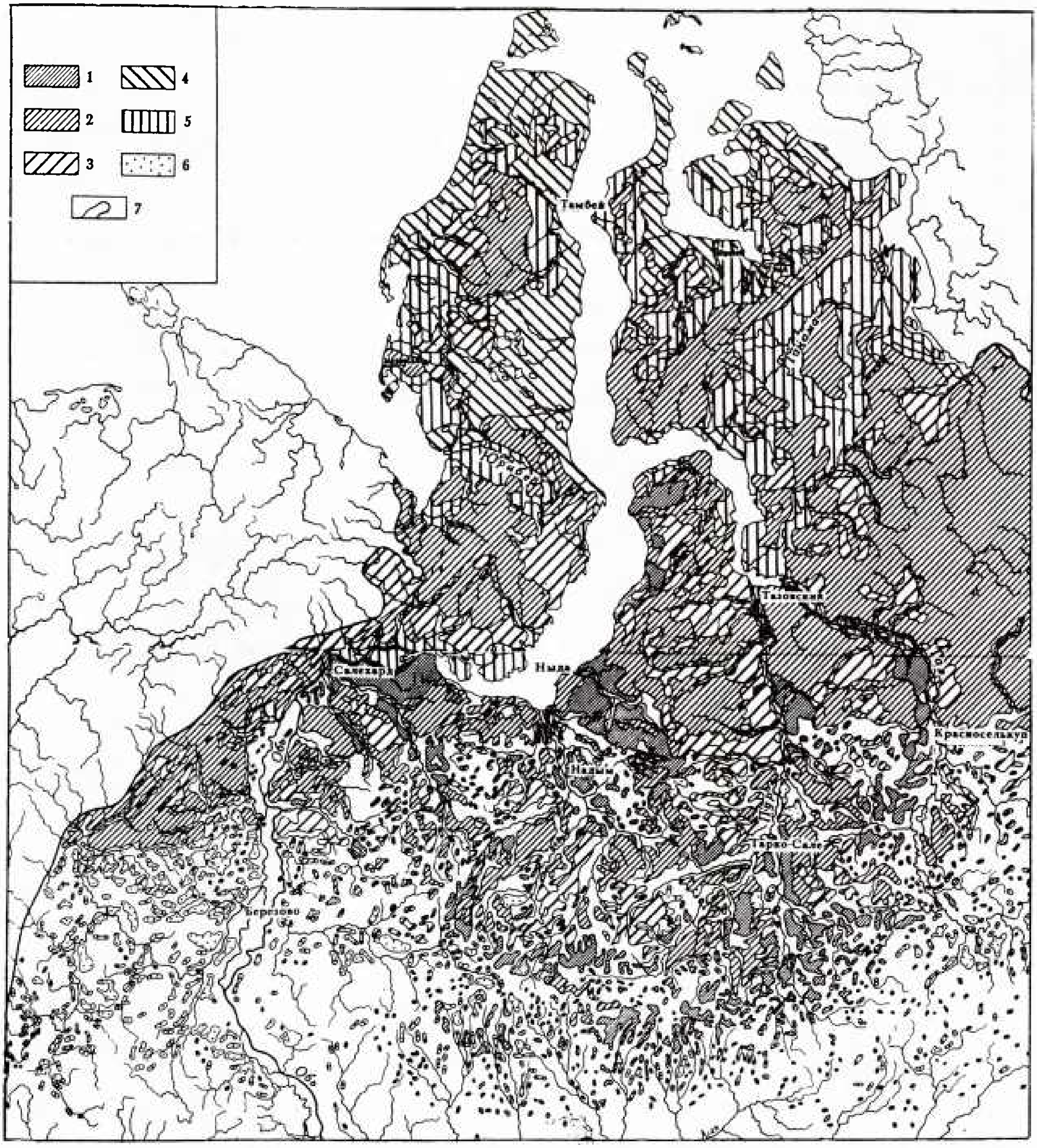


Figure A36d. Genetic types and ice content of the top 10-m section of permafrost on the western Siberian platform (compiled by U.B. Badu and V.T. Trofimov). (From Trofimov et al. 1980a.)

Legend - Figure A36d

1 - epicryogenic primarily low-ice-content types (moisture content of combined soils below minimum of plasticity, sands below full moisture capacity);

2 - epicryogenic primarily average-ice-content types (moisture content of combined soils below maximum of plasticity, sands below or close to full moisture capacity);

3 - epicryogenic primarily heavy-ice-content types (moisture content of combined soils higher than maximum of plasticity, sands above full moisture capacity, peat above 50%);

4 - syncryogenic heavy-ice-content types;

5 - syncryogenic primarily heavy-ice-content types thickness to 3-6 m, underlain by epicryogenic average- and high-ice-content types;

6 - epicryogenic primarily heavy-ice-content types, alternating on small areas with talik types;

7 - boundary of permafrost, genetic types of permafrost, and types with various ice contents.

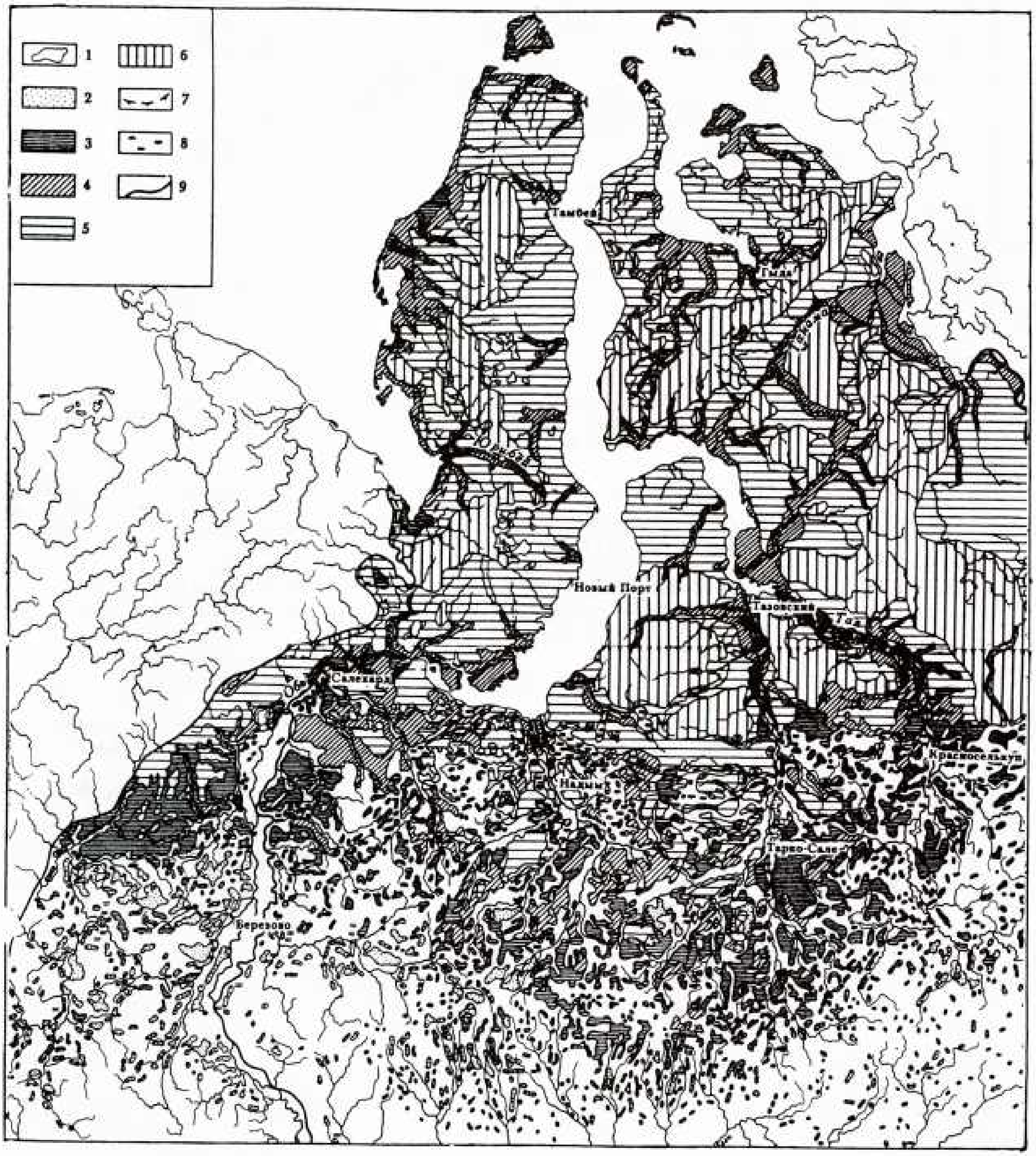


Figure A36e. Thickness of permafrost on the western Siberian platform (compiled by A.V. Gruzdov, U.B. Badu, V.S. Varenyshev, V.T. Trofimov, N.G. Firsov). (From Trofimov et al. 1980a.)

Legend - Figure A36e

1 - boundary of distribution of permafrost and regions with various thickness;

2 - predominant thickness of permafrost to 10 m;

3 - from 10 to 50 m;

4 - from 50 to 150 m;

5 - from 150 to 300 m;

6 - greater than 300 m;

7 - boundary of territories that have established or supposed wide distribution of kriopegs, which are cooled grounds, saturated liquid saline water below 0°C associated with permafrost or ice-free permafrost with saline pore water;

8 - plots of development of discontinuous permafrost;

9 - boundary of outcrops of Paleozoic rock of the Urals.

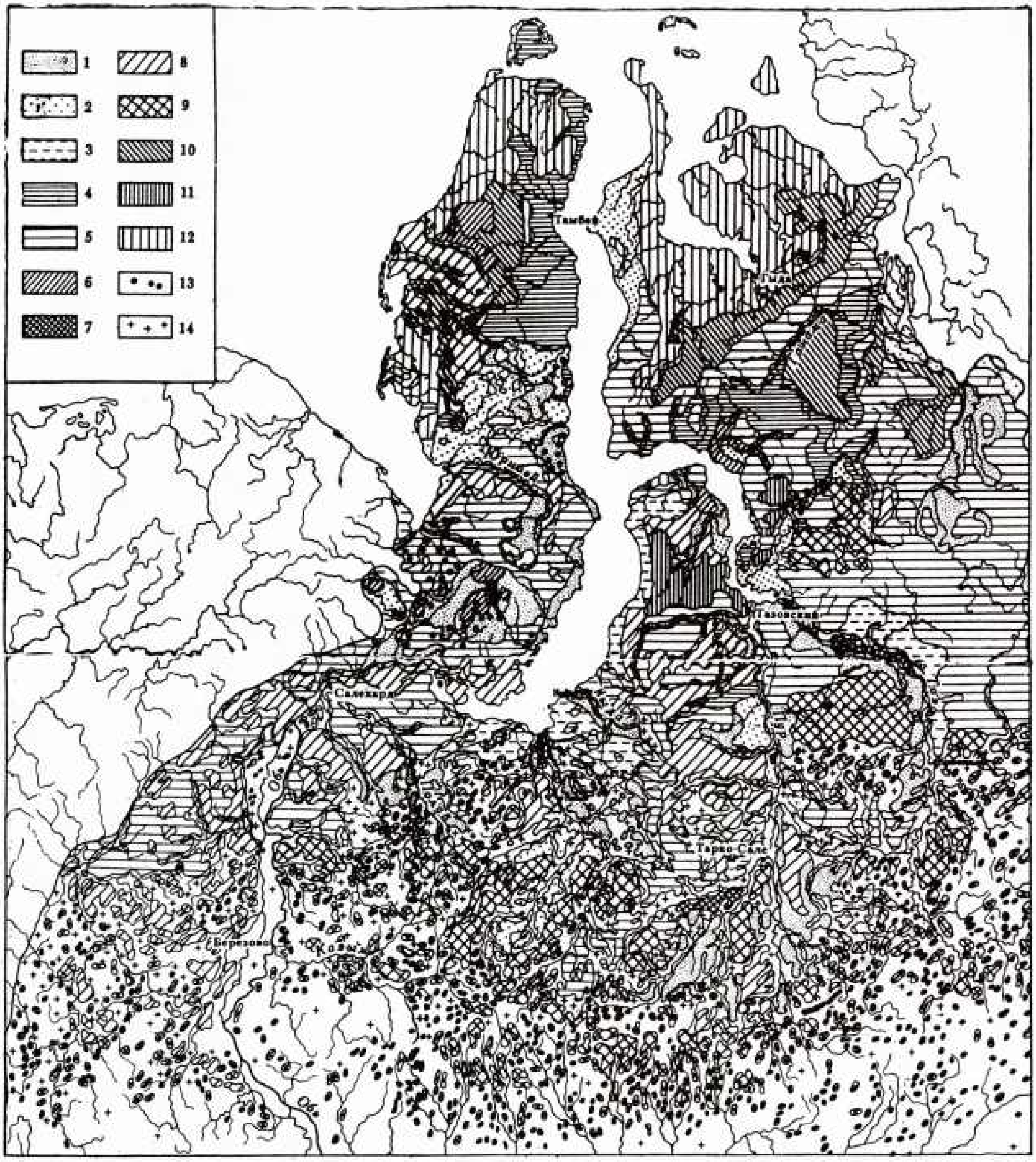


Figure A36f. Magnitude of potential settlement by thawing of the top 10-m permafrost layer of the western Siberian platform. (From Trofimov et al. 1980a.)

Legend - Figure A36f

1 - potential settlement of thawing (S) <0.5 m in low-ice-content, primarily sandy to sandy-silty loam soils;

2,3 - S = 0.5-1.0 m (2 - in ice-rich, primarily sandy to sandy-silty loam soils, overlapped by up to 2 m of peat in the southern part of the territory; 3 - in low-ice-content primarily clayey silty loam-clay soils);

4,5 - S = 1.0-3.0 m (4 - in ice-rich, primarily sandy to sandy-silty loam and interbedded by sandy-clayey soils with polygonal wedge ice thickness 2-5 m or overlapped by peat in the southern part of the territory; 5 - in average-ice-content, primarily clayey silty loam-clayey soils, overlapped by peat in the southern regions);

6-10 - S = 3.0-5.0 m (6 - in ice-rich, primarily sandy silty loam-sandy and interbedded by sandy-clayey soils, overlapped by peat thickness to 2 m; 7 - in the same soils, overlapped by peat of thickness 2-4 m and occasionally more; 8 - in ice-rich, primarily clayey silty loam-clayey soils, overlapped by peat of thickness to 2 m; 9 - in the same soils, overlapped by peat of thickness 2-4 m occasionally more; 10 - in the same soils, with polygonal wedge ice of thickness 2-5 m);

11-12 - S > 5.0 m (11 - in ice-rich, clayey silty loam-clayey soils; 12 - in the same soils, with polygonal wedge ice thickness to 6-12 m);

13 - regions with catastrophic settlements in interbedded sandy-clayey soils, incorporating deposits of injected and sheet ice;

14 - primarily frozen soils with small islands of permafrost

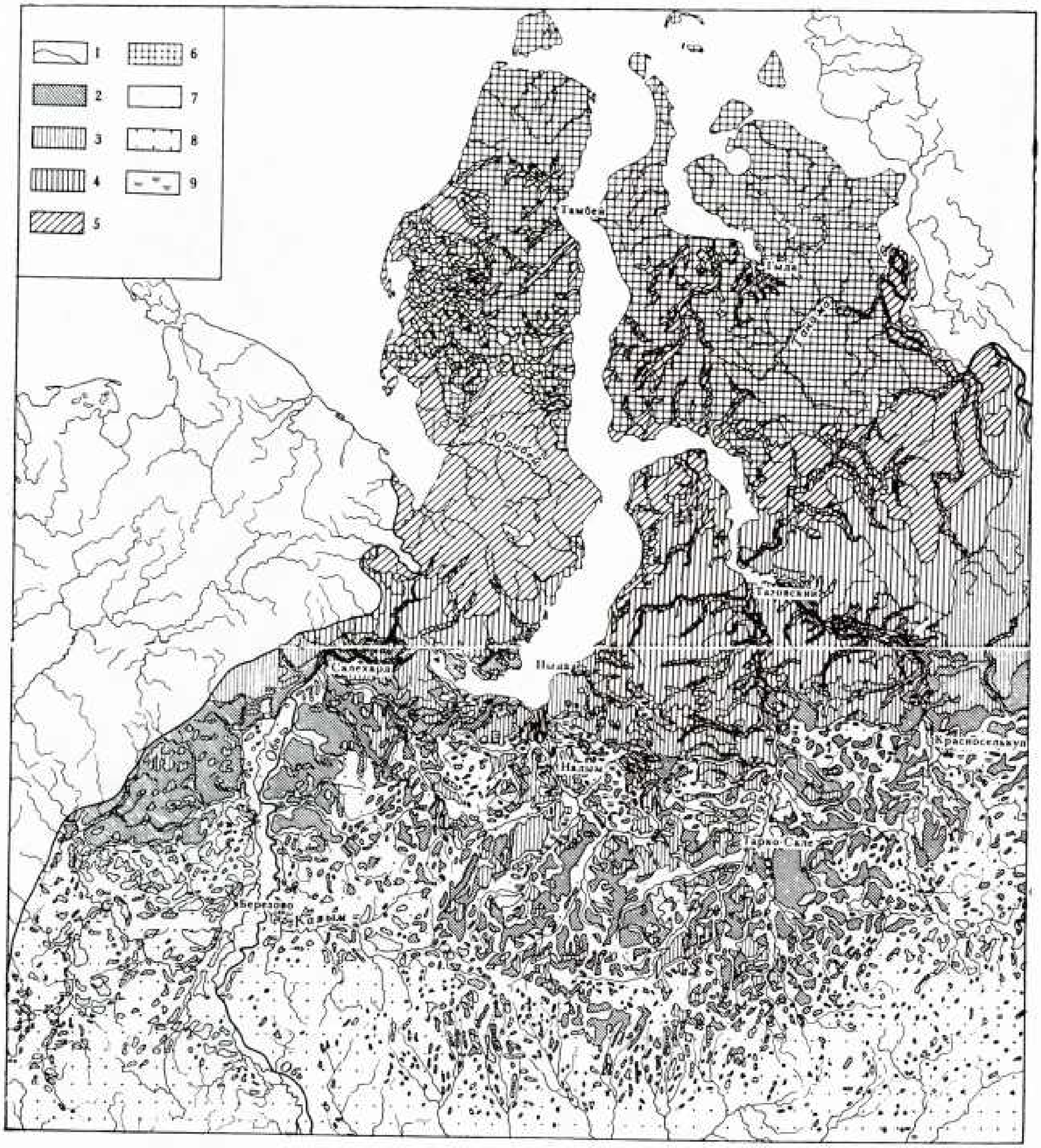


Figure A36g. Distribution of average annual temperatures of permafrost (compiled by A.V. Giruzdov, U.B. Badu, E.P. Lobov, P.I. Kashperyuk, V.T. Trofimov, and N.G. Firsov). (From Trofimov et al. 1980a.)

Legend - Figure A36g

1 - Boundary of permafrost distribution and regions of various temperature;

Predominant permafrost temperatures (°C):

2 - from 0° to -1°;

3 - from -1° to -3°;

4 - from -3° to -5°;

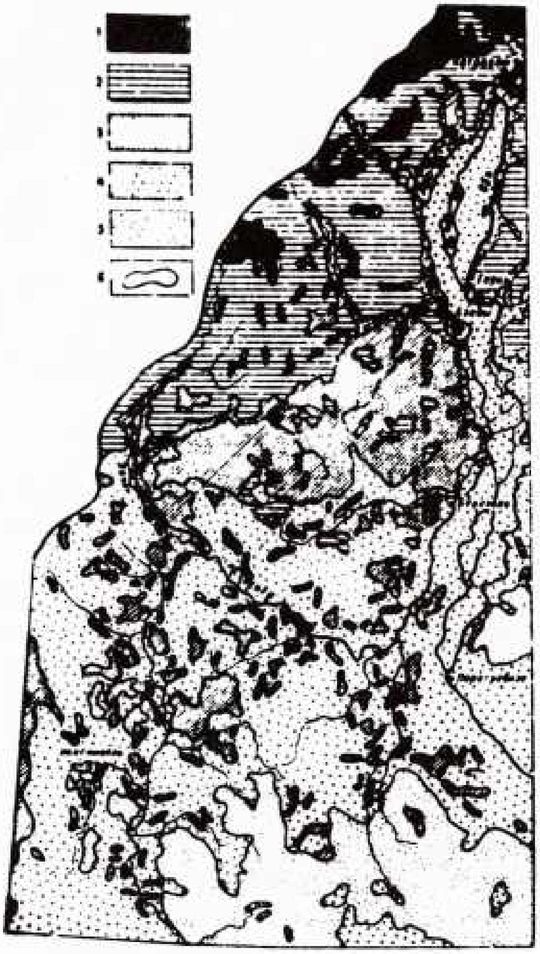
5 - from -5° to -7°

6 - from -7° to -10°

7 - Area with common alternation between permafrost and unfrozen ground with temperatures close to 0°;

8 - Talik ground with temperatures from 0° to 2-3°;

9 - Areas of distribution of discontinuous permafrost.



Legend - Figure A37

1 - temperature -1° to -3°C;

2 - 0° to -2°C;

3 - +0.5° to -2°C;

4 - +1° to -0.5°C;

5 - >1°C;

6 - boundaries of regions with different temperatures.

Figure A37. Average annual ground temperature distribution of the northwestern part of the west Siberia platform (Trofimov et al. 1980b.)

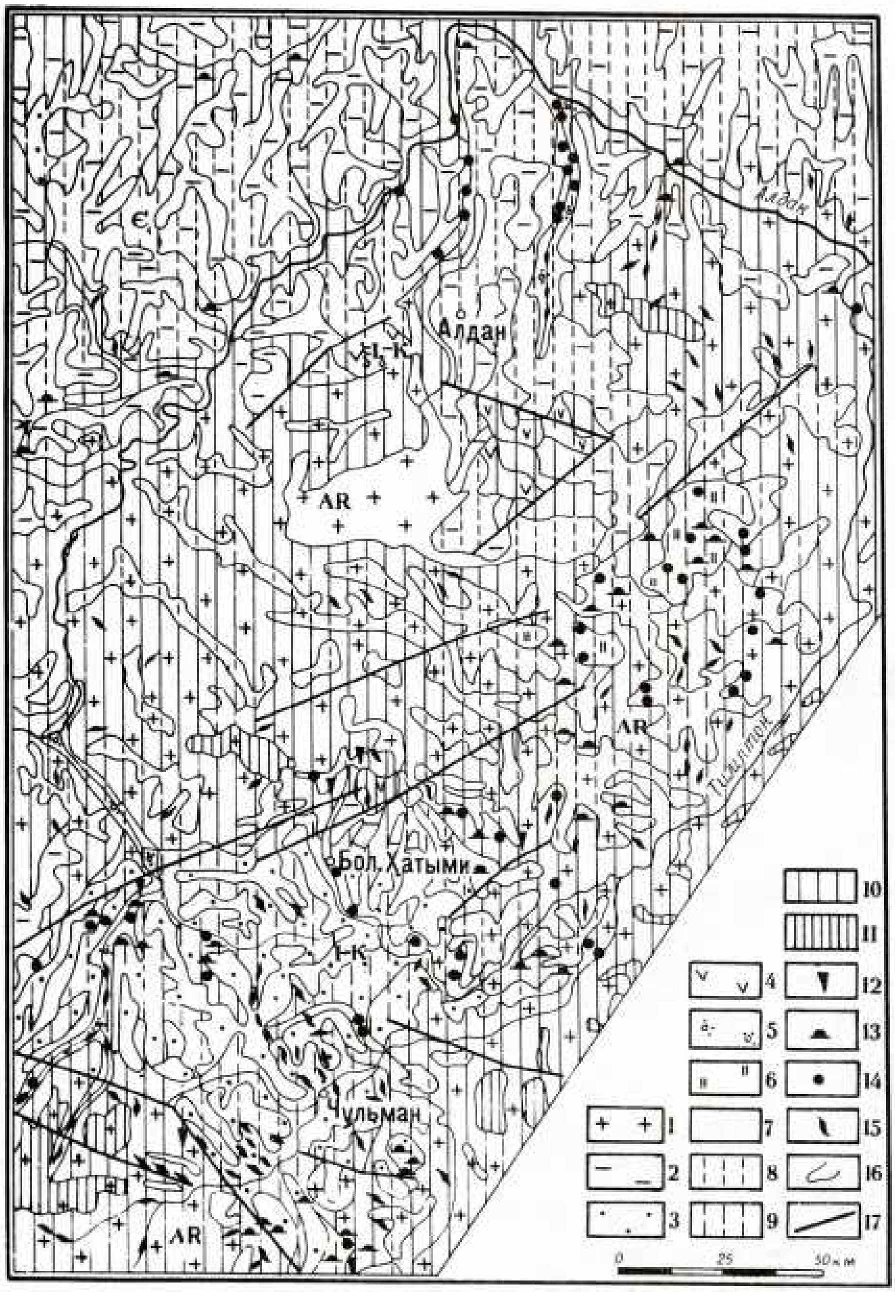


Figure A38. Permafrost map of the Aldano-Timptonic interfluve. (From Trush and Chizhova 1980.)

Legend - Figure A38

Geology:

1 - gneisses, shales, granitoids (AR), cryogenic texture (KT) fissured, fissure-veined;

2 - dolomites, marls, limestones (E_1; KT), fissured-karst-stratum;

3 - sandstones, aleurites, argillites, coals (T-K, KT), fissured, fissured-stratum;

4 - syenite-porphyry, porphyry (ε, T_3-K);

5 - alluvial gravel, sands, sandy-silty loams, peat formation (a w-IY), icy, (KT) various;

6 - lake-swamp peatlands (BB IY), ice-rich, with reticulate and ataxitic cryogenic texture;

Permafrost:

7 - permafrost with island distribution, temp 0° to -0.5°C, thickness (T) to 50 m;

8 - massive-island permafrost, temp -0.5° to -1.0°C, T to 100 m;

9 - discontinuous, temp -1° to -2°C, T to 200 m;

10 - continuous, temp -1° to -3°C, T 100 to 300 m;

11 - continuous, temp -3° to -5°C, T 200 to 500 m;

Cryogenic phenomena:

12 - wedge ice;

13 - frost mounds;

14 - thermokarst;

15 - icing of underground water;

16 - geological boundaries;

17 - tectonic fractures.

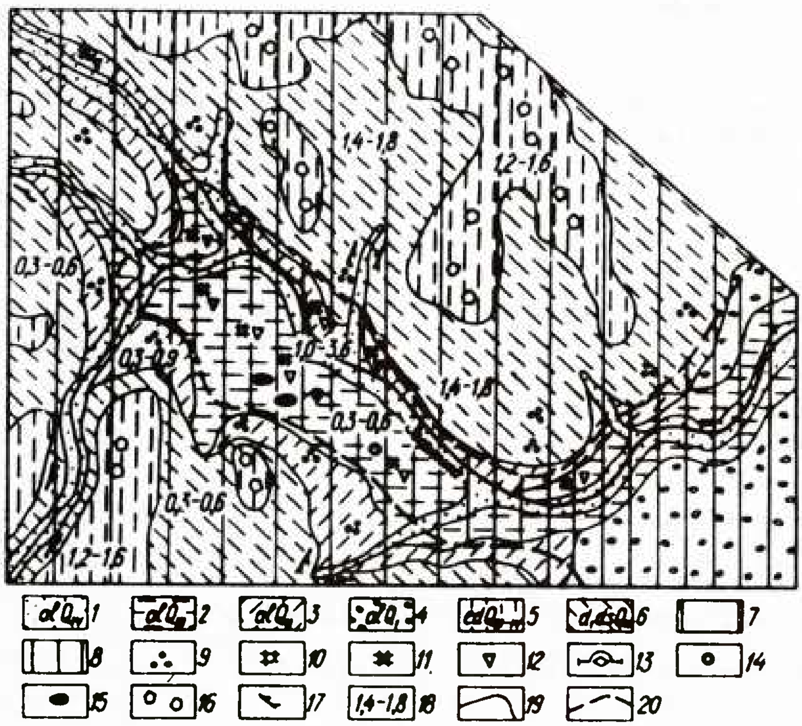


Figure A39. Geocryology of the Zyryanka River's central portion. (From Vasil'ev and Dorofeev 1978.)

Legend - Figure A39

Quaternary deposits:

1 - recent (al QIV);

2 - upper Quaternary, first upper floodplain terrace (al QIII);

3 - middle Quaternary of the base terrace (al QII);

4 - lower Quaternary (al QI);

5 - undifferentiated contemporary and upper Quaternary (ed QIII-IV);

6 - recent (d, ds QIV).

Mountain permafrost:

7 - thickness to 200 m and temperature -2° to -4°C;

8 - thickness to 250 m and temperature to -6°C.

Cryogenic formations:

9 - small polygonal microrelief;

10 - high-center polygonal microrelief;

11 - low-center polygonal microrelief;

12 - wedge-ice;

13 - frost mounds with injected ice;

14 - thermokarst pits and polygonal canals with water;

15 - thermokarst lakes;

16 - nonsorted circles [spot medallions];

17 - solifluction sheets and lobes.

Other symbols:

18 - depth of summer thaw;

19 - boundaries of genetic deposits;

20 - boundaries of permafrost types.

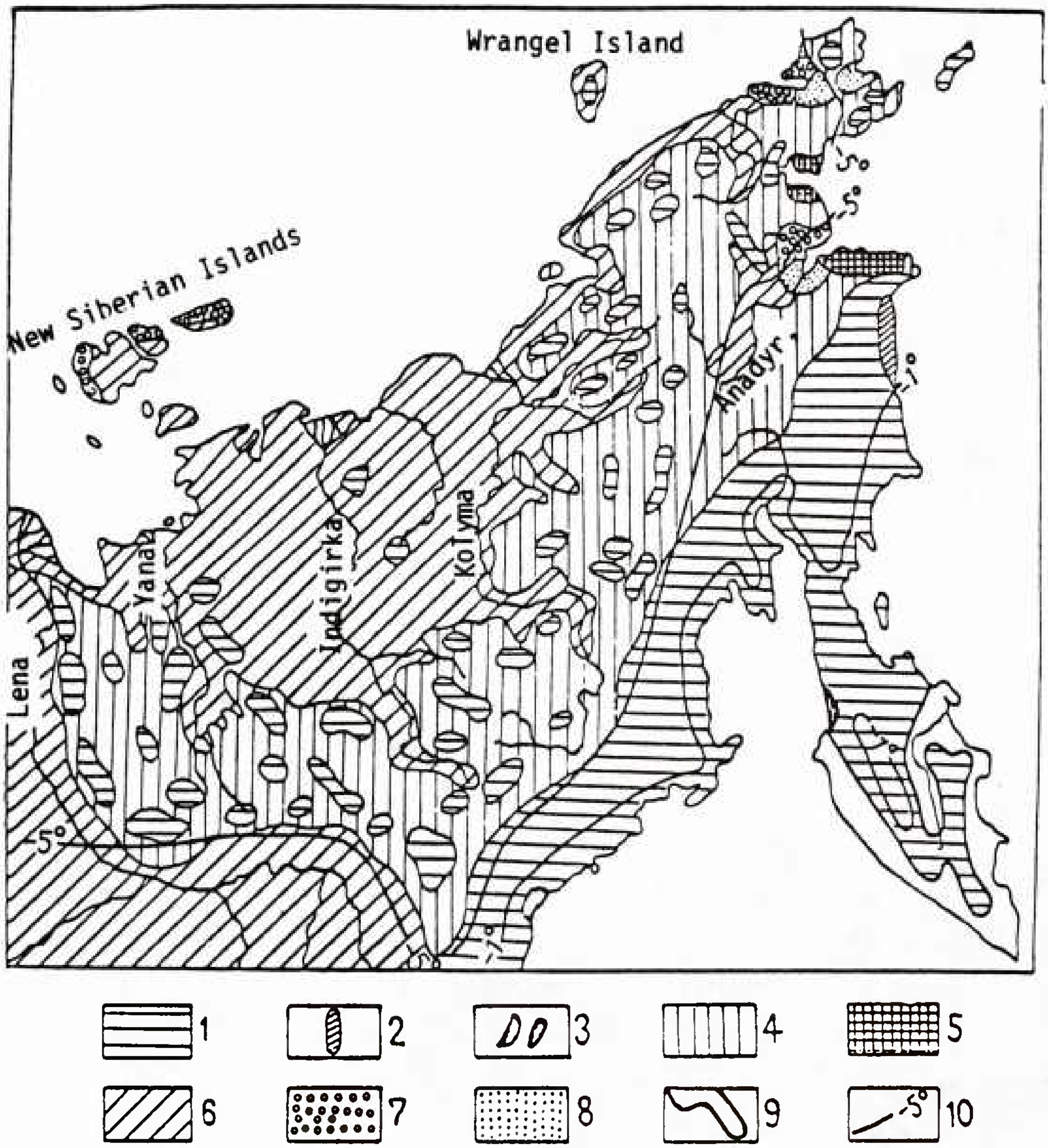


Figure A40. Schematic cryological regionalization of the northeast USSR. (From Vtiurin 1980.)

Legend - Figure A40

Province of monogenetic permafrost

Region of epigenetic permafrost:

1 - districts with simple form of cryogenic structure, without an ice bed;

2 - district with complex form of cryogenic texture, with sheet segregated and injected ice.

Region of syngenetic permafrost:

3 - districts with simple form of cryogenic texture (tentatively isolated).

Province of polygenetic permafrost

Region of epi-syngenetic permafrost with two horizons:

4 - districts with simple form of cryogenic structure;

5 - districts with complex forms of cryogenic structure, with sheet ice in the epigenetic horizon;

6 - districts with complex forms of cryogenic structure, with ice wedges in the syngenetic horizon;

7 - districts with very complex forms of cryogenic texture, with sheet ice in the epigenetic horizon, and with ice veins in the syngenetic horizon.

Region of multi-horizon, syn-epi-syn-epigenetic permafrost:

8 - districts with undetermined form of cryogenic structure (tentatively isolated);

9 - southern boundary of permafrost distribution (according to Baranov 1956);

10 - geoisotherm (according to Baranov 1956).

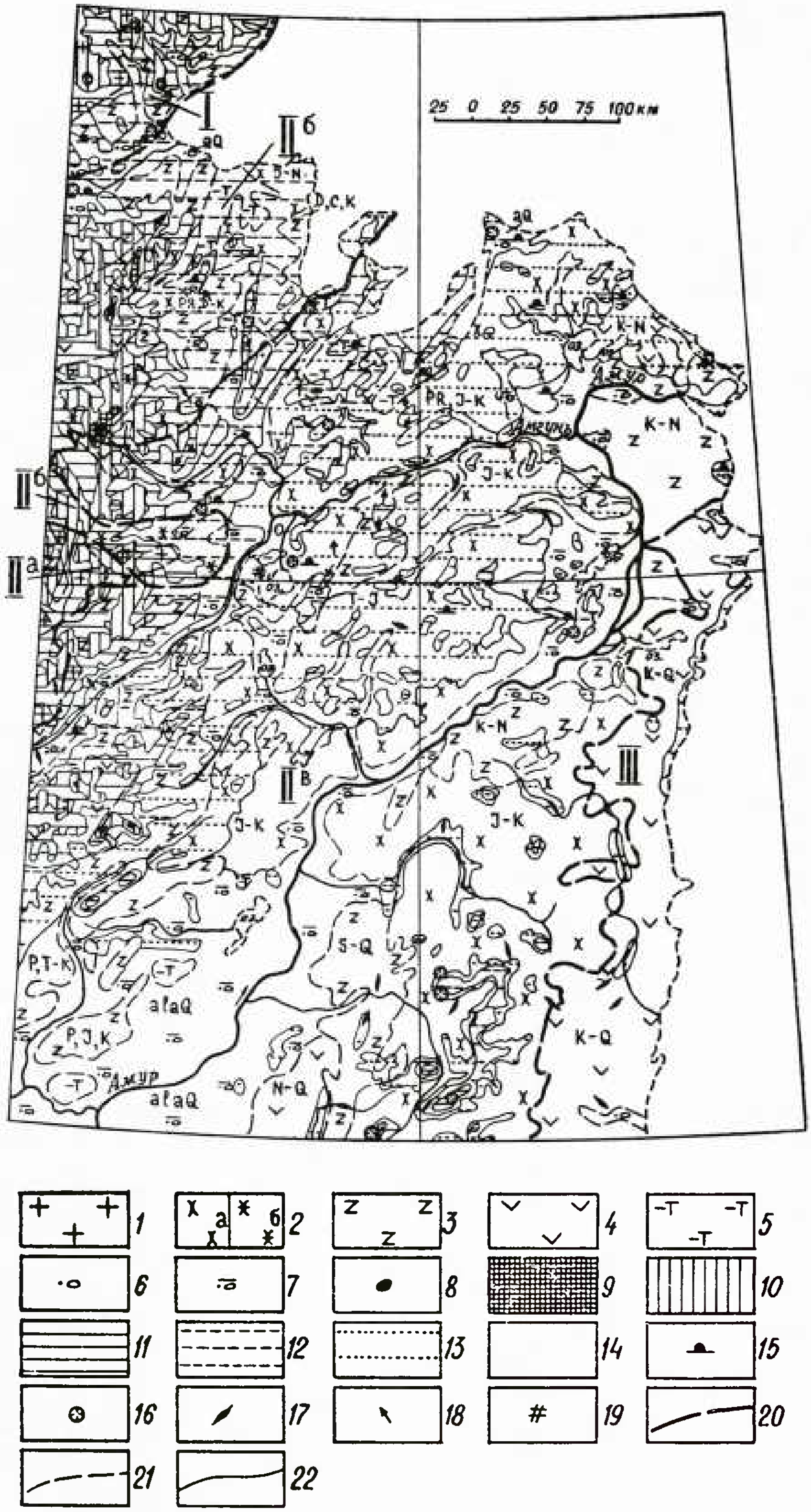


Figure A41. Permafrost of the southern part of the Far East. (From Zamolotchikova and Smirnova 1978.)

Legend - Figure A41

Geology-structural zones:

I - Siberian platform;

II - Amyr folding region;

IIa - Bureinski land mass;

IIb - Mongolo-Okhotskaya folding system;

IIB - Sikhote-Alinskaya volcanogenic system;

Formation of mountain rocks:

1 - metamorphic (AR,PR) gneisses, shales, amphiboles;

2 - terrigenous (PR, D, T-K) a - sandstones, aleurites, conglomerates, gritstones, clay and flint shale. 6 - the same rock types but schistose;

3 - effusive-terrigenous (, S-K);

4 - effusions and tuffs of acid, neutral, basic and mixed makeup.

All formations of rocks are interrupted by intrusions, especially large and numerous in the areas of metamorphic formation development.

Makeup and geologi-genetic types of Quaternary deposits:

5 - peat (b) underlain and sometimes replaced by sandy silty loam and clayey silty loam deposits (a, la);

6 - sand-gravel deposits (a, m);

7 - sandy silty loam and clayey silty loam deposits, underlain by sandy gravel (a, la);

Permafrost conditions: distribution, thickness and temperature of rock

No.	Distribution of permafrost and talik	Avg. annual temp. (°C) Permafrost	talik	Permafrost thickness (m)
8	continuous	-5 to -7	--	200-500
9	continuous	-3 to -5	--	100-300
10	almost continuous	-1 to -3	--	50-150
11	discontinuous	0 to -2	0 to +1	0-100
12	islands with bits	0 to -1	0 to +3	0-50
13	primarily unfrozen with rare permafrost islands & bits	0 to -0.5	0 to +4	0-20
14	Unfrozen with occasional permafrost bits	0	>+1	--

Areas of developing cryogenic phenomena:

15 - frost mounds;

16 - thermokarsts;

17 - icing;

18 - solifluction;

19 - polygonal relief;

Boundaries:

20 - geologi-structural zones;

21 - geological;

22 - types of permafrost.

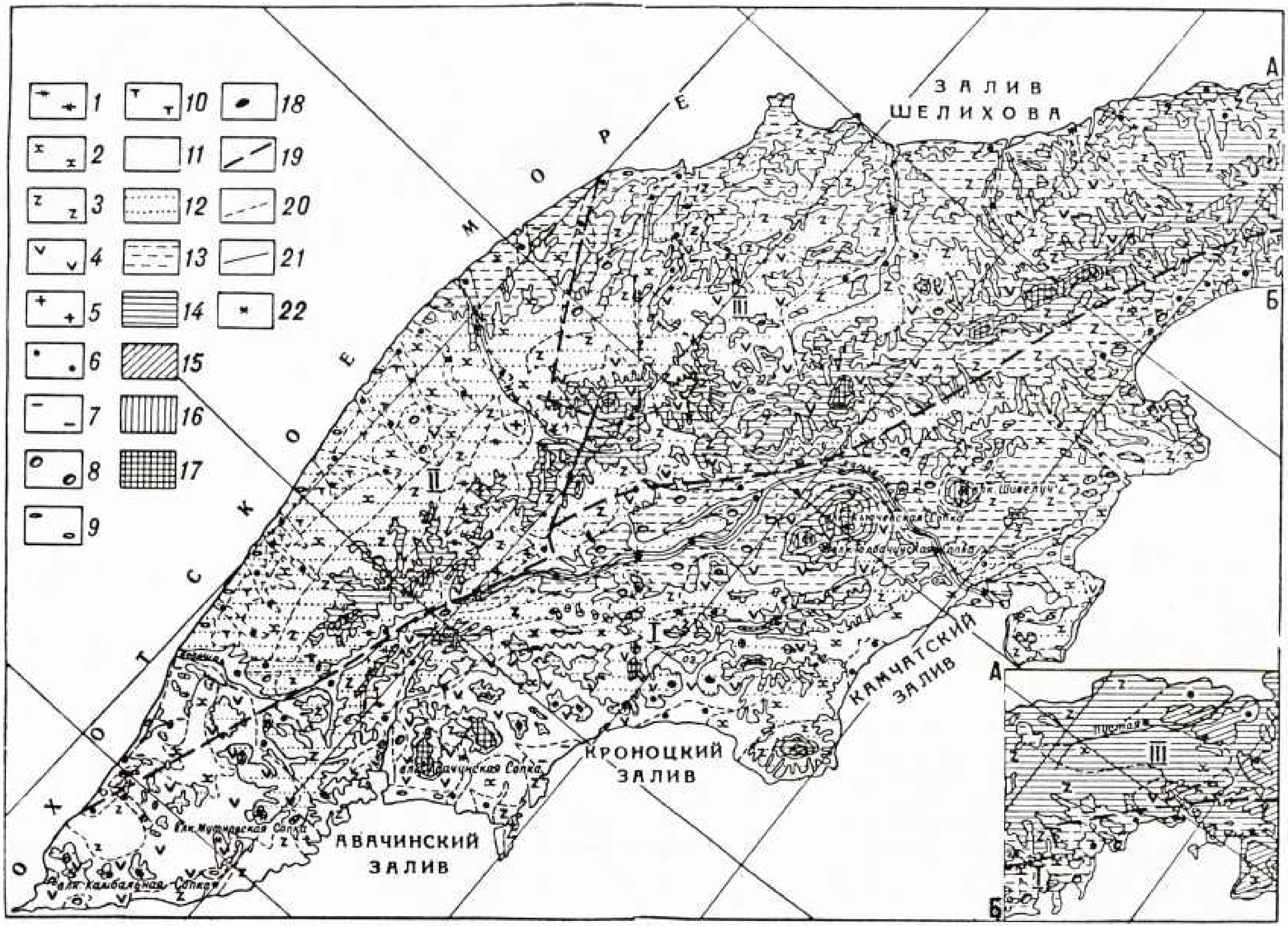


Figure A42. Kamchatka rock temperatures. (From Zamolotchikova and Smirnova 1979.)

Legend - Figure A42

Geological-structural zones:

I - Kirilo-Vostochno-Kamchatka geosynclinal folding system;

II - Ohtsko-Kamchatka massif;

III - Ohotsko-Koryakska folding system.

Formation of mountain rock:

1 - metamorphic (PT, PZ): gneisses, shales, amphibolites, migmatites, schists;

2 - terrigenous (P, N): sandstones, aleurites, argillites, conglomerates, coals;

3 - volcanic-terrigenous (K, P, N): (2) above alternate with basalt, andesites, tuffs, jaspers;

4 - volcanogenic (N, Q): basalts, andesite-basalts, andesites, tuffs;

5 - intrusive, primarily of granitoid make up (PZ, K, N).

Contents of loose Quaternary deposits:

6,7 - sands, sandy silty loams with pebbles;

8 - sands, sandy silty loams with gravel, pebbles and cobbles;

9 - gravel-pebble deposits with sandy filler;

10 - peat, turf.

Distribution and average annual temperature of frozen [T(f)] and unfrozen [T(t)] rock:

11 - unfrozen T(t) > 3°C;

12 - unfrozen with sporadic permafrost T(t) 0° to 3°C;

13 - unfrozen with rare islands of permafrost T(f) 0° to -0.5°C, T(t) 0° to 3°C;

14 - island permafrost T(f) 0° to -1°C, T(t) 0° to 3°C;

15 - discontinuous permafrost T(f) 0° to -2°C;

16 - primarly continuous permafrost T(f) -1° to -3°C;

17 - island, discontinuous, continuous permafrost T(f) 0° to -5°C, T(t) 0° to 12°C;

18 - continuous permafrost T(f) -3° to -5°C, on the peaks to -10°C.

Borders:

19 - structural zones;

20 - geological zones;

21 - temperature zones;

22 - volcanoes.

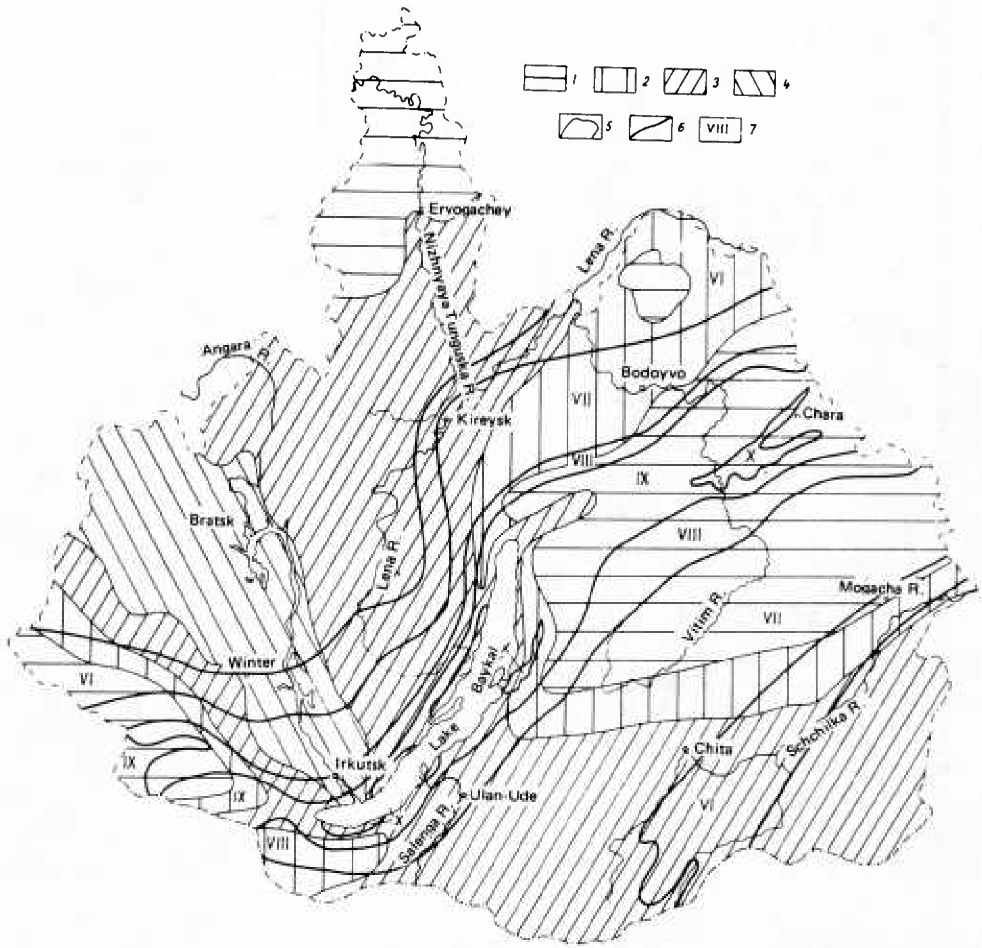


Figure A43. Permafrost and seismic zoning in eastern Siberia (compiled by N.Ye. Zarubin, based on data developed by L.N. Orlova, F.N. Leshchikov, V.P. Solonenko and others). (From Zarubin and Pavlov 1980.)

Legend - Figure A43

1 - regions of continuous permafrost;

2 - regions with large masses of frozen ground;

3 - regions of permafrost islands (rare islands and pockets of frozen ground);

4 - regions of deep seasonal freezing with short-term and scarce pockets of frozen ground;

5 - boundaries of regions with permafrost with varying discontinuity;

6 - boundaries of seismic zones;

7 - intensity of earthquakes expressed in points on the scale.

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